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ENVIRONMENTAL PROTECTION MEASURES, COMPETITIVENESS AND PRODUCTIVITY

SEPTEMBER 1994

Ontario

Ministry of
Environment
and Energy

ISBN 0-7778-2724-7

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SEPTEMBER 1994

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PIBS 3228E

ENVIRONMENTAL PROTECTION MEASURES, COMPETITIVENESS AND PRODUCTIVITY

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Report prepared for:
Ontario Ministry of Environment and Energy

ACKNOWLEDGEMENT AND DISCLAIMER

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Executive Summary

Background

The Ontario Government is undertaking major changes to its environmental protection regimen. New environmental regulations will effect major changes in the ways in which industrial operations deal with the wastes they generate.

Much debate has arisen over the possible impacts of environmental protection regulations upon affected firms. Business critics of the Province's proposed programs focus on the potential negative effects of the programs on industrial productivity and the consequent slippage in international competitiveness. Proponents of the programs point to the necessity to make these investments and of the industrial opportunities (direct and indirect) which frequently result from a proactive approach to environmental protection.

The economics literature is not conclusive regarding the net impact of environmental protection regulations on competitiveness and productivity. The limited empirical research that has been conducted relates almost exclusively to the impacts of environmental regulations in the United States. Much less work has been done on quantifying the net impacts of regulations in Canada.

Study Objectives

The study's objectives are three-fold:

(i) to postulate mechanisms and hypotheses whereby environmental protection regulations affect industrial competitiveness and productivity;

(ii) to test these hypotheses empirically; and

(iii) to forecast the impacts of Ontario's proposed environmental protection measures on the competitiveness and productivity of selected sectors and firms in Ontario.

Fulfilling these objectives is an ambitious undertaking. Assessment of regulatory impacts is very complex and often controversial. No one study can offer the definitive answer as to how environmental protection measures affect the competitiveness and productivity of regulated firms.

Nonetheless, this study offers a theoretical and empirical framework to facilitate research into these issues, and applies the framework to Ontario's pulp and paper, iron and steel and petroleum refining sectors.

Competitiveness and Productivity

Despite its current popularity as a buzzword, "competitiveness" is not well-defined. The complexity of the concept is illustrated by the *World Competitiveness Report* which analyzes 330 interactive determinants of international competitiveness.

Given the controversy in defining competitiveness, it is not surprising that no consensus exists on how to measure competitiveness. Diverse measures of competitiveness have been proposed, depending on the level of analysis (national, sector or firm) and the aspect of competitiveness of primary interest. The following measures of competitiveness are among the most frequently used.

Frequently Used Measures of Competitiveness

Measure	Nation	Sector	Firm
Current Account Balance	✓		
Market Share	✓	✓	✓
Index of Determinants	✓	✓	✓
Relative Profitability		✓	✓
Relative Unit Costs		✓	✓
Relative Productivity		✓	✓

One of the few common themes of the literature is the important contribution of productivity growth to industrial competitiveness. As an operational measure of competitiveness, relative productivity has significant advantages over other measures. These advantages include:

- the belief of many prominent analysts that productivity is the primary determinant of competitiveness;
- the existence of well developed techniques for measuring productivity;
- the existence of analytical frameworks for estimating regulatory impacts on productivity; and
- the existence of a relatively large number of studies estimating the impacts of environmental protection measures on productivity in foreign jurisdictions.

For these reasons, relative productivity, the productivity of Ontario firms compared to the productivity of competitors in other jurisdictions, was selected as this study's measure of industrial competitiveness. Regulatory impacts on industrial productivity in Ontario are compared to regulatory impacts on industrial productivity in other jurisdictions. The net effect represents the impact of environmental regulations on competitiveness.

Environmental Regulations and Industrial Productivity

Environmental regulations may affect productivity through many diverse channels. This study enumerates 13 hypothesized transmission channels. A representative sample of these hypotheses is summarized below.

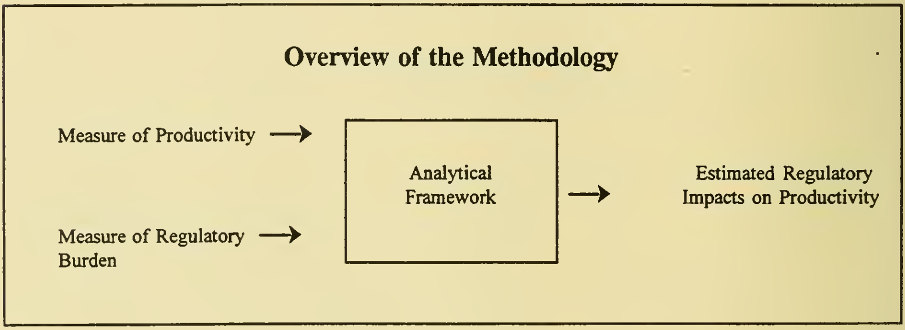
Selected Hypotheses Regarding Environmental Regulation-Productivity Linkages

Channel	Hypothesis
Diversion of Inputs	▸ Productivity Decreases If Environmental Regulations Force Firms to Devote Inputs to Pollution Control Activities that Do Not Contribute to Marketable Output
Capital Efficiency	▸ Productivity Decreases If Old Source/New Source Distinctions Retard Capital Turnover ▸ Productivity Increases If Environmental Regulations Accelerate Capital Turnover
Input Substitution	▸ Productivity Decreases if Environmental Regulations Cause Firms to Switch to More Expensive or Less Efficient Materials or Energy Sources
R&D Expenditures	▸ Productivity Decreases If Environmental Regulations Divert R&D from Process Innovation and Product Development ▸ Productivity Increases If Pollution Control R&D Results in Cost Saving Process Innovation and Development of Marketable Products

Environmental regulations have been widely examined as a possible reason for the slowdown in productivity growth occurring in many industrialized nations since the early 1970s. Dozens of studies have tested one or more of the hypotheses enumerated in this report. Unfortunately, these studies do not provide a consensus on the magnitude of the impacts. Findings vary significantly depending on the analytical framework and the data employed.

Methods Used to Estimate Regulatory Impacts on Productivity and Competitiveness

Understanding the study's methodology is critical to interpreting the empirical results. The methodology involves: (i) defining a measure of regulatory burden; (ii) defining a measure of competitiveness and productivity; and (iii) applying an analytical framework to determine the relationship between (i) and (ii).


Overview of the Methodology
Measure of Productivity
Measure of Regulatory Burden
Analytical Framework
Estimated Regulatory Impacts on Productivity

Measuring Industrial Productivity

The multi-factor productivity of Ontario firms was measured using publicly available financial data and the following formula:

$$\text{Productivity} = \frac{\text{Output}}{c_k(\text{Capital Services}) + c_{lem}(\text{Labour, Energy and Material Inputs})}$$

where: output is defined as sales or revenue; capital services are defined as returns to capital (earnings); labour, energy and material inputs are the associated operating costs; and c_k and c_{lem} are the share of total costs accounted for by each set of inputs.

Measuring Historical Regulatory Impacts on Productivity

Regulatory burden in the past is measured as "pollution intensity indices" derived from provincial data on direct discharges to waterways from industrial plants. These indices include discharges relative to a base year and discharges per unit of sales. If productivity declines as pollution intensity decreases, then environmental regulations which reduce pollution intensity may have an adverse impact on productivity.

Three techniques were used to assess the relationship between productivity performance and past pollution intensity. First, graphs depict the trends over time in productivity and pollution intensity, allowing readers to assess any visible relationships. Second, correlation statistics provide a formal measurement of any relationships between productivity and pollution intensity. Finally, the influence of pollution intensity, capital utilization, exchange rates and other firm-specific variables on productivity performance is assessed using regression analysis.

Measuring Future Regulatory Impacts on Productivity

Regulatory burden in the future is measured as the estimated costs to comply with proposed regulations under the Municipal-Industrial Strategy for Abatement (MISA), Ontario's program to control effluent discharges. The productivity impacts of expenditures on possible air pollution control programs are also examined.

To project future regulatory impacts, a growth accounting framework is used to estimate changes in productivity and productivity growth had the regulations been applied in the past. The growth accounting framework assumes that expenditures on environmental protection force firms to reduce expenditures on other inputs on a dollar-for-dollar basis. Productivity measures are recalculated under the assumption that the estimated costs of complying with possible air and water regulations reduce the inputs available to produce marketable output.

Measuring Regulatory Impacts on Competitiveness

The above analytical methods provide estimates of the impact of Ontario's regulations on industrial productivity. To assess regulatory impacts on competitiveness, these estimates are compared to estimates of regulatory impacts on industrial productivity in other jurisdictions.

In this study, estimates of regulatory impacts on productivity are derived for three Ontario industrial sectors: pulp and paper; iron and steel; and petroleum refining. However, comparable estimates of regulatory impacts on industrial productivity in other jurisdictions are available only for the U.S. pulp and paper and iron and steel industries.

It is important to realize that the methodology described above was selected in the face of significant constraints. Several preferred approaches to the empirical assessment of regulatory impacts on industrial productivity and competitiveness were found to be unfeasible due to the limited data available.

Nevertheless, the methodology selected was deemed sound. Various checks, described in the body of the report, were undertaken to justify confidence in the following results.

Findings: Historical Regulatory Impacts

There is no consistent evidence that Ontario industrial productivity has been affected by changes in pollution intensity. This result held for all three of the sectors examined.

Estimates of regulatory impacts on productivity in other jurisdictions are available for the U.S. iron and steel and pulp and paper industries. Evidence suggests that U.S. environmental regulations have negatively affected U.S. iron and steel manufacturers. Evidence for the U.S. pulp and paper mills is inconclusive.

Comparing our results for Ontario industries and the limited evidence from the U.S. suggests that Ontario industrial competitiveness, as measured by relative productivity, was not likely harmed by the province's environmental protection programs.

For Ontario industries to have suffered a net competitive disadvantage from environmental regulations, regulations in other jurisdictions would have had to *improve* the productivity of Ontario's competitors.

Findings: Projected Regulatory Impacts

The results indicate that future regulatory impacts on industrial productivity are likely to be small. If the most stringent regulatory scenarios are imposed for both MISA and CAP, the following declines in productivity are possible. No impact on productivity growth was evident.

Maximum Projected Impacts of Water and Air Protection Policies on Ontario Industrial Productivity

Sector	Change in Average Productivity Levels
Pulp and Paper	-0.76%
Iron and Steel	-1.63%
Petroleum Refining	-0.20%

As an indication of the magnitude of these changes, consider that the most stringent combination of air and water regulations would reduce an index of productivity in the pulp and paper industry from 100.0 to 99.2. Such changes are dwarfed by normal cyclical fluctuations in productivity.

When confronted in the past with regulatory requirements, these industries have often proved capable of seeking innovative compliance strategies that offer some offsetting benefits. Therefore, it is reasonable to believe that firms' compliance strategies will generate some offsetting benefits. Since the above estimates do not take into account any offsetting benefits, the projections should be considered upper bound estimates of future regulatory impacts.

Unfortunately, projections of regulatory impacts are not available for other jurisdictions. Therefore, the impact of these changes in productivity on the industries' competitiveness, as measured by relative productivity, remains unknown.

Conclusions

This study finds no clear evidence that the competitiveness or productivity of key Ontario industrial sectors have been impaired by past environmental regulations. Furthermore, projected impacts of possible water and air protection programs on these sector's competitiveness and productivity are likely to be small.

Although in the worst case regulations are expected to reduce productivity by less than 2%, these programs are not the only forces acting upon firms. For example, environmental regulations pertaining to management of solid and hazardous waste are making demands upon and presenting opportunities to Ontario industry. In this time of restructuring, successful corporate strategies must also consider factors such as rapidly changing technology and new trading rules. Assessing in isolation the impacts of one set of environmental regulations presents only a limited approach.

Given its complexity and relevance to policy formation, the topic of regulatory impacts on competitiveness is deserving of on-going research. In particular, this study recommends the following actions:

- Expand the Analysis to Include Other Measures and Determinants of Competitiveness
- Develop an Inventory of Estimates of Regulatory Impacts on Industries in Other Jurisdictions
- Develop More Extensive Data Sources

1.0 Introduction

1.1 Background

The Ontario Government is undertaking major changes to its environmental protection regimen. One of the main targets of the Province's new regulations will be the air- and water-borne contaminants released to the environment by the industries in the Province. Programs such as the Municipal-Industrial Strategy for Abatement (MISA) will effect major changes in the ways in which industrial operations deal with the wastes they generate. Pollution prevention will, ultimately, be the design criterion, but in the interim the Province's various environmental protection programs will ensure that industries make significant progress in reducing their loadings of contaminants to the environment.

Much debate has arisen over the possible impacts of environmental protection regulations upon affected firms. Business critics of the Province's proposed programs focus on the potential negative effects of the programs on industrial productivity and the consequent slippage in international competitiveness. Proponents of the programs point to the necessity to make these investments and of the industrial opportunities (direct and indirect) which frequently result from a proactive approach to environmental protection.

The economics literature is not conclusive regarding the net impact of environmental protection regulations on competitiveness and productivity. The limited empirical research that has been conducted relates almost exclusively to the impacts of environmental regulations in the United States. Much less work has been done on quantifying the net impacts of regulations in Canada.

1.2 Purpose

A number of important gaps in the understanding of the effects that environmental regulations might have on industrial productivity and competitiveness remain. The purpose of this study is to fill some of these gaps, specifically by:

1. postulating mechanisms and hypotheses whereby environmental protection regulations affect industrial competitiveness and productivity;
2. testing these hypotheses empirically; and
3. forecasting the effects of Ontario's proposed water and air pollution requirements on the competitiveness and productivity of selected sectors and firms in Ontario.

1.3 Report Format

This report contains 8 chapters and several appendices. The report can be divided into four broad topics: background theory and a summary of evidence to date; developing methodology for our own quantitative estimates of regulatory impacts on Ontario competitiveness and productivity; reporting of our detailed findings; and conclusions. In particular, the chapters contain the information summarized below.

Chapters 2 and 3: Background Theory and Evidence to Date

Despite their frequent citation in public policy debates, competitiveness and productivity remain difficult concepts with which to work. Therefore, the report begins with two chapters that provide overviews of competitiveness and productivity, respectively, and assess the possible relationships between these concepts and environmental protection measures. More specifically, competitiveness and productivity are discussed in two separate chapters containing:

- definitions of the concepts;
- possible quantitative measures;
- inventories of hypotheses regarding ways in which environmental protection regulations could affect the measures; and
- reviews of the empirical evidence specific to each hypothesis.

Chapter 4: Methodology and Data Sources

Chapter 4 presents the methodology used in this study for estimating regulatory impacts on competitiveness and productivity. Details regarding constraints on choice of methodology, data sources and reasons for adopting the particular methodology used are provided.

Chapter 4 is key to understanding and interpreting our results. Although somewhat technical in nature, it is highly recommended that readers thoroughly acquaint themselves with the material in the chapter before turning to the results.

Chapters 5, 6 and 7: Estimated Impacts By Industry

The methodology is applied to three of Ontario's industrial sectors which have been subject to environmental protection regulations: pulp and paper; petroleum refining; and iron and steel. Results are summarized in three industry-specific chapters.

Chapter 8: Conclusions

The final chapter reiterates key elements of the methodology, summarizes the industry-specific findings and reports our general conclusions regarding past and future impacts of Ontario environmental protection measures on the competitiveness and productivity of the three industrial sectors examined.

2.0 Competitiveness and Environmental Regulations

Summary

Despite its currently popularity as a buzzword, the term "competitiveness" is not clearly defined. The complexity of the concept hinders practical analysis of industrial competitiveness. For example, the *World Competitiveness Report* analyzes 330 interactive determinants of international competitiveness.

Given that defining competitiveness is controversial, it is not surprising that no consensus exists on how to measure competitiveness. Diverse measures of competitiveness have been proposed, depending on the level of analysis (national, industry or firm) and the aspect of competitiveness of primary interest. The most popular measures of competitiveness are: the current account balance; various market shares; indices of competitiveness determinants; relative unit costs; relative profitability; and relative productivity.

One of the few themes recurring in the literature is the important contribution of productivity growth to industrial competitiveness. Many prominent analysts assert that relative productivity is the only meaningful measure of competitiveness.

A wide range of hypotheses exist regarding the impact of environmental regulations on measures of competitiveness. These hypotheses include both positive impacts and negative impacts. Unfortunately, little empirical work has been undertaken to test these hypotheses. Indeed, analytical frameworks to address many of the hypotheses have not been developed.

Relative productivity is the one exception to this rule. There is a highly developed body of literature hypothesizing and quantifying the relationship between environmental regulations and productivity. This literature can be used to measure regulatory impacts on *relative* productivity.

For both theoretical and practical reasons, relative productivity was selected as this study's working measure of competitiveness. Chapter 3 examines productivity in more detail.

The term competitiveness is currently a popular "buzzword" of both the business and political communities, often denoting whatever the user wants the term to mean. Much of the confusion on the topic stems from the fact that competitiveness is extremely complex and affected by virtually every aspect of the economy. An example of the term's complexity is found in the 1991 *World Competitiveness Report* which analyzes 330 interactive determinants of international competitiveness (World Economic Forum, 1991).[1]

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[1] See Appendix A for full references.

This chapter of the report clarifies some of the issues surrounding competitiveness and environmental protection measures by examining:

- how competitiveness has been defined;
- how competitiveness has been measured;
- how environmental protection measures could affect competitiveness (hypothesized transmission channels); and
- the evidence of actual regulatory impacts on measures of competitiveness.

The findings of this analysis are then used to begin focusing on possible ways to assess the actual impacts of Ontario environmental regulations on the competitiveness of the province's economy.

2.1 Competitiveness Defined

With the advent of a global economy, the vast majority of literature on competitiveness examines the concept from an international context. In fact, it has been stated that the only way to look at competitiveness is from a global perspective (World Economic Forum, 1991). This is particularly true for Ontario where 35% of the value of goods produced are exported and 41% of the value of goods consumed are imported (Premier's Council, 1988).

The following comprise some of the most widely adopted definitions of competitiveness.

- The *World Competitiveness Report* (World Economic Forum, 1991) defines competitiveness at three levels:
    (i) national competitiveness is the "extent to which a national environment is conducive or detrimental to business;"
    (ii) sector competitiveness is the "extent to which a business sector offers potential for growth and attractive return on investment;" and
    (iii) firm competitiveness is the "ability to design, produce and/or market products superior to those offered by competitors, considering both price and non-price characteristics."
- The U.S. President's Report on Industrial Competitiveness in 1985 stated "competitiveness is the degree to which a nation, under free and fair market conditions, produces goods and services that meet the test of international markets while simultaneously maintaining and expanding the real incomes of its citizens" (Furino, 1988).

- Jones and Teece (1988) offer two definitions of competitiveness:

  i) "competitiveness is the ability of an economy's GDP and GNP per capita to grow as fast as any other major economy;" and

  ii) "competitiveness is the degree to which a nation, in a world of open markets, produces goods and services that meet the tests of the marketplace while simultaneously expanding GNP and GNP per capita at least as fast as any other major trading economy."

- Porter (1990) states that "... there is not even an accepted definition of the term 'competitiveness' as applied to a nation." Instead, Porter states that "the only meaningful concept of competitiveness at the national level is *productivity.*" Through continual innovation in new production technologies, new ways of doing business, new products, etc., a country becomes competitive only by increasing its relative productivity.

2.2 Measures of Competitiveness

The above definitions of competitiveness do not suggest a single, unambiguous way of measuring competitiveness. Analysts have developed a variety of measures that can be applied at one or more analytical level: national; sector; and firm. Table 2.2.1 lists the most important of these measures and the analytical levels to which they apply. Each measure is discussed below.

Table 2.2.1
Measures of Competitiveness Specific to Each Analytical Level

Measure	Nation	Sector	Firm
Current Account Balance	✓		
Market Share	✓	✓	✓
Index of Determinants	✓	✓	✓
Relative Profitability		✓	✓
Relative Unit Costs		✓	✓
Relative Productivity		✓	✓

The *current account balance* (exports minus imports) is used as a means of measuring competitiveness at the national level. Countries with a current account surplus are exporting more goods than they import, thereby indicating that they are able to compete in global markets.

However, a country's current account balance is not an unambiguous measure of competitiveness since the current account balance can fluctuate for reasons that do not necessarily represent changes in competitiveness. For example, if a current account surplus is achieved only as a result of wage cuts, then the standard of living will decline in that country. As an increased standard of living is a goal of competitive nations, it is preferable that a current account surplus be a reflection of increased efficiency rather than wage cuts (Premier's Council, 1988). Similarly, a short-term current account surplus can be achieved by unsustainable exchange rate policies. This clearly does not reflect the underlying competitiveness of an economy.

Market share can be defined differently according to each level of analysis. Some of the most common measures of market share are the following.

- National Level

    - the domestic economy's share of total foreign consumption
    - the domestic economy's share of total world production
    - the domestic economy's share of total world exports

- Sector Level

    - the domestic sector's share of domestic output from all sectors
    - the domestic sector's share of foreign production for that sector
    - the domestic sector's share of foreign consumption of that product group
    - the domestic sector's share of total world exports for that sector

- Firm Level

    - the domestic firm's share of the domestic sector's output
    - the domestic firm's share of foreign consumption of that product group
    - the domestic firm's share of foreign production for that sector
    - the domestic firm's share of total world exports for that sector

Although many definitions exist for market share, their interpretations are all similar: larger market shares indicate greater competitiveness.

Indices of Determinants have also been used to measure competitiveness. Various determinants of competitiveness are aggregated into an index of competitiveness by weighting determinants according to their perceived importance to competitiveness.

The *World Competitiveness Report*, produced annually by a Swiss-based academic consortium, is the most comprehensive example of a competitiveness index. The report ranks the international competitiveness of 34 countries by quantifying 330 determinants of competitiveness, weighting the determinants according to their relative importance, and aggregating them into a single index for each country. The determinants include many of the competitiveness measures listed in Table 2.2.1.

The Canadian Manufacturers' Association (1991) uses a similar approach in calculating its "Canadian Competitiveness Index." The CMA index incorporates three factors: unit labour costs, the selling prices of manufactured goods traded domestically and internationally, and Canada's balance of payments.

Relative profitability is also used as a measure of international competitiveness at the firm or sectoral level. For example, a firm which enjoys a larger profit margin vis-a-vis its international competitors is regarded as being more competitive in the world market. Profit margins can be defined in several ways, including return on equity and return on sales.

It is important, however, to examine long-term relative profitability, rather than short-term profitability. Short-term profitability can be influenced by many factors that do not necessarily impact on a firm's or sector's ability to compete in international markets. Long-term relative profitability indicates which firms have the ability to consistently outperform their rivals in the marketplace (Ernst & Young, 1990).

Relative Unit Costs represent the sum of expenditures on inputs needed to produce one unit of physical output. Since production costs are a significant determinant of competitiveness, relative unit costs can be viewed as a measure of a firm's or sector's ability to compete in the marketplace.

Difficulties in measuring relative unit costs arise since rarely are products made by different firms exactly the same. Therefore, unit costs are often not directly comparable. It is also important to note that there are many examples of firms competing successfully in open markets despite having high unit costs (Lazar, 1991).

Relative Productivity is the ratio of output produced to inputs consumed in producing the output. It is discussed fully in Chapter 3 of this report.

2.3 Determinants of Competitiveness

It is not clear from the literature what effect environmental protection measures may have on competitiveness at the firm, sector or national level. Therefore, it is worthwhile to develop an overview of the determinants of competitiveness. This will provide a context for studying the exact ways in which environmental protection measures may influence competitiveness.

The most exhaustive study of the determinants of international competitiveness is the *World Competitiveness Report* (WCR). The WCR assesses the international competitiveness of 34 countries through 330 determinants (called "criteria" in the WCR) covering a wide range of issues. These determinants are listed in Appendix B.

Certain determinants are deemed more influential than others in determining international competitiveness. Therefore, the most influential determinants are given a greater weighting in the index. In particular, those determinants believed to be most influential are weighted twice as heavily as other factors ("double weighted").

In order to provide a framework for determinants, the WCR groups them into eight subject "factors:"

Factor I	Domestic Economic Strength	Factor V	Infrastructure
Factor II	Internationalization	Factor VI	Management
Factor III	Government	Factor VII	Science and Technology
Factor IV	Finance	Factor VIII	People

Each factor is briefly reviewed below.

Factor I Domestic Economic Strength

This factor gives an overall evaluation of the domestic economy in which firms are situated. The economic performance as expressed by the components of national accounts, the change in economic activity and the nature and competitive strength of value-adding activities are the key areas examined. Determinants included in this factor include size of the economy, investment, inflation and economic growth.

Determinants in this factor which are double weighted: domestic savings, increase in consumer price inflation, and retail sales.

Factor II Internationalization

This factor describes the extent to which a country participates in the international trade and investment flows. It utilizes the performance in trade and investment, participation in the international economy, openness to foreign business interest and foreign market penetration as key determinants of competitiveness. Determinants used in this factor include terms of trade, exports, imports, protectionism, and flexibility.

Double weighted determinants are: terms of trade index and exchange rate index.

Factor III Government

The extent to which government policies are conducive to competitiveness is measured in this factor. These include, the impact of the state, legislative and regulatory environment, monetary and fiscal policies, nature of the competitive environment, socio-political stability and adaptiveness to change. Determinants in this factor include government debt and reserve, tax revenues and rates indicating monetary and fiscal policy, environmental protection regulations and the effectiveness of anti-trust legislation.

Double weighted determinants are: central government foreign debt and indirect tax revenues.

Factor IV Finance

The performance of capital markets and the quality of financial services are measured in this factor by examining the availability of finance, and the diversity and efficiency of capital markets. Determinants include, interest rates, size of banks, financial alternatives indicate the nature of capital markets in the country. The availability of venture capital and the responsiveness of capital markets to the needs of business indicate a country's entrepreneurial risk-taking ability.

The double weighted criterion is real short-term interest rates.

Factor V *Infrastructure*

Infrastructure describes the degree to which resources and systems are adequate to serve the basic needs of business. Availability and efficient utilization of natural resources and the adequacy and flexibility of infrastructure in supporting business needs are the research categories for this factor. These determinants include imports of oil, the relative burden of energy costs, self-sufficiency in natural resources, and recycling.

There are no double weighted determinants in this factor.

Factor VI *Management*

This factor examines the degree to which enterprises are managed in an innovative, profitable and responsible manner. It evaluates the entrepreneurial drive and quality of management, customer orientation, product and service quality, and business efficiency. Examples of determinants included in this factor are: indicators of product quality, labour costs, manufacturing productivity, competitive pricing, use of technology, and managerial orientation. Of particular importance is aggregate productivity as measured by GDP per capita.

Double weighted determinants are: aggregate productivity, change in aggregate productivity and labour costs.

Factor VII *Science and Technology*

Scientific and technological capacity together with success of basic and applied research is examined in this factor. It is done so by looking at R&D expenditure, R&D personnel, intellectual property generation and public-business cooperation. Determinants include, number of scientists in industry, patents, search for new technologies, and business expenditures on R&D.

There are no double weighted determinants in this factor.

Factor VIII *People*

The qualifications and availability of a nation's human resources is evaluated in this factor. Population characteristics, educational structures and employment structures are examined. Attitude of the workforce and quality of life are also looked at. Determinants include, employment, educational levels, motivation and skills of the workforce, and growth and structure of the population. Quality of life is determined by comparing income distribution and costs of living.

The double weighted criterion is public expenditure on education.

This list of determinants of competitiveness is the most complete compilation available. By stipulating which determinants are double weighted, the WCR index also provides a means of selecting those determinants which are most important. By this criterion, the key determinants of competitiveness are:

- aggregate productivity;
- changes in aggregate productivity;
- labour costs;
- central government foreign debt;
- indirect tax revenues;
- terms of trade index;
- exchange rate index;
- interest rates; and
- public expenditures on education.

Of primary importance to this study is that environmental protection regulations are not among the determinants considered most important in the WCR index. However, if environmental regulations affect any of the key determinants listed above, then the indirect effects of environmental regulations upon competitiveness may be significant.

In order to verify that the determinants incorporated into the WCR are representative of other approaches, several other studies of competitiveness were also reviewed. It was found that the WCR approach followed quite closely those adopted elsewhere. For example, the Premier's Council of Ontario (1988) discusses many of the determinants covered in the WCR but reduce the primary determinants to two closely related factors: relative productivity and labour costs.

However, one prominent analyst has a somewhat different view of the determinants of competitiveness. Porter (1990) believes that the prevailing thinking on the determinants of competitiveness is fundamentally flawed. In particular, he argues that many of the variables people use to measure competitiveness do not provide an accurate indication of the competitiveness of an economy. For example, the use of exchange rates and interest rates as determinants of competitiveness ignores many of the facts: Japan and South Korea have achieved rapidly increasing living standards despite budget deficits; Germany and Switzerland despite relatively high currencies; and Italy and South Korea despite high interest rates. Similarly, Porter argues that competitiveness as a function of cheap labour neglects countries such as Germany and Sweden which have prospered while enduring high wages and labour shortages.

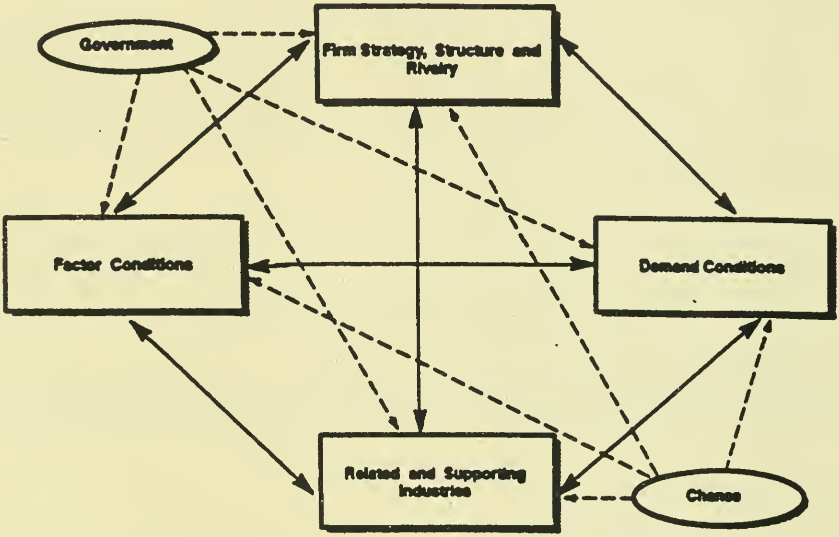
Porter uses a new approach, dubbed the "Diamond of National Advantage," to determine what enables certain industries within a country to become and remain competitive. There are four facets of the diamond: Factor Conditions, Demand Conditions, Related and Supporting Industries, and Firm Strategy, Structure and Rivalry. Exhibit 2.3.1 provides a schematic overview of the diamond of national advantage.

Factor Conditions include a country's position in the basic production inputs such as labour, land, natural resources and infrastructure. Additionally, this attribute includes specialized areas such as advanced skills and technology.

Demand Conditions entail the nature of the domestic market for the output of local industries. Particularly important is the presence of demanding domestic customers which motivate industries to innovate.

Exhibit 2.3.1

National Determinants of Competitive Advantage: "The Diamond"


Government
Firm Strategy, Structure and Rivalry
Factor Conditions
Demand Conditions
Related and Supporting Industries
Chance

Source: Porter (1991) Figure 7

Related and Supporting Industries examines the presence, or absence, of supplier industries and other related industries that are internationally competitive. This includes suppliers that are integral to the innovation in the industry, as well as innovative local companies in industries related by technology, skills or customers.

Firm Strategy, Structure, and Rivalry looks at the conditions in a country affecting how companies are created, organized and managed, as well as the nature of domestic rivalry.

Two additional variables noted are government and chance. Government policy affects the four determinants of competitive advantage included in the diamond by influencing firms' decision-making behaviour, goals, roles as buyers or sellers of goods, and influences on the competitive environment. Chance events are developments which are outside of a country's control and which influence its competitive advantage. Examples include war, new technologies, and certain economic and legal developments. These events may create or destroy opportunities for a country's firms to strengthen their competitive advantage.

While the diamond offers an explanation of why some countries are more competitive than others, it is the companies within those countries which ultimately compete, not the countries themselves. Therefore, Porter feels that looking at the competitiveness of a nation is attempting to answer the wrong question. Rather, the true underpinning of competitiveness according to Porter is productivity. Hence, the major concerns are the determinants of productivity, and the rate of productivity growth of specific industries and industry segments. A nation's standard of living depends on the capacity of its companies to achieve high levels of productivity, and to continually upgrade their productivity levels.

Although Porter takes a different route from other analysts, it is clear that he ends up at a similar position. There is a wide consensus that relative productivity is a fundamental determinant of competitiveness.

2.4 Hypothesized Transmission Channels and Empirical Evidence

The above review of the determinants of competitiveness indicate that environmental protection measures are, at most, just one of many forces that may influence competitiveness. However, the specific channels through which environmental protection measures and competitiveness may be related remain uncertain.

This chapter of the report attempts to identify possible transmission channels using two approaches:

- Approach #1

  Environmental protection regulations may influence directly the measures of competitiveness cited above. Therefore, we examine possible transmission channels through which this may occur.

- Approach #2

  Environmental protection measures may impact indirectly on competitiveness by affecting the determinants of competitiveness. Therefore, we examine the WCR determinants of competitiveness to identify those determinants which environmental protection measures may affect and the transmission channels through which the determinants may be affected.

Approach #1 Transmission Channels and Measures of Competitiveness

Recall from Table 2.2.1 that popular measures of competitiveness are the current account balance, market shares, competitiveness indices, relative profitability, relative unit costs and relative productivity. Hypotheses regarding the impact of environmental regulations upon each measure of competitiveness are discussed below. In addition, the available empirical evidence regarding the magnitude of the impacts through each channel is summarized.

Current Account Balance

As identified in Section 2.2, the current account balance is one measure of competitiveness at the national level. An increase in the current account surplus indicates that a country's exports are successfully competing in global markets.

Environmental protection measures may influence the current account balance through four hypothesized transmission channels.

Hypothesis #1 Current Account Balance Decreases if Regulated Industries Increase Output Prices

Domestic producers may raise their output prices to recover abatement costs. If foreign product prices remain constant, then the relative price of domestically produced goods will increase. Exports will tend to fall, while imports will tend to rise. Hence the current account balance will also fall, indicating that there has been a decrease in the competitiveness of domestic producers.

Hypothesis #2 Current Account Balance Increases if Regulations Decrease Aggregate Domestic Demand

If environmental regulations have an overall dampening effect on the economy, aggregate consumer demand would decrease. This would tend to decrease imports, thereby increasing the current account balance.

While this is a way in which environmental protection regulations could influence a measure of competitiveness, it would be incorrect to attribute the resulting changes in the current account to increased competitiveness. This provides an example of a weakness in the current account balance as a measure of competitiveness.

Hypothesis #3 Current Account Balance Decreases if Regulations Necessitate Importing Pollution Control Capital

A third channel by which environmental regulations may affect the current account balance is through the importation of environmental protection goods and services. For example, regulations may require firms to invest in abatement technology which is not available from domestic sources. Therefore, imports of abatement capital would increase and the current account balance would tend to decline.

Hypothesis #4 Current Account Balance Increases if Regulations Create a Competitive Environmental Protection Goods and Services Industry

It is possible that regulations could create domestic demand for environmental goods and services, thus allowing the development of a strong domestic environmental protection industry. If aggressive, this domestic industry may generate export sales, thereby increasing the current account balance.

Empirical Evidence

Table 2.4.1 summarizes the available empirical estimates of the impact of environmental regulations on the current account. For example, "+" or "-" indicates that environmental regulations have effected a net increase or decrease in the current account balance. The estimates are generally produced by netting out pollution abatement and control expenditures from models of the economy.

Note that none of the studies account for any changes in the import and export of environmental protection goods and services. Therefore, the empirical evidence captures only the first two hypotheses. The individual impacts of these two hypotheses cannot be disaggregated from the net estimate.

Recall further that changes in the current account due to hypothesis #2 should not be interpreted as changes in industrial competitiveness. Yet the impacts of hypothesis #2, as well as hypothesis #1, are captured within the estimates. Since the individual impacts of the two hypotheses are not separated, the estimates do not necessarily reflect changes in competitiveness.

Table 2.4.1 indicates that the net impact of the first two hypotheses is inconclusive. Although some studies indicate that environmental regulations in the U.S. have had a negative impact on that country's current account balance, other studies have estimated a positive or nil effect.

No studies were found which estimated the impact of the last two hypothesized channels through which environmental regulations may impact upon the current account balance. Currently, the U.S. Environmental Protection Agency is examining highly disaggregated trade data which may provide estimates of U.S. trade in environmental protection goods and services.[2]

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[2] Dr. Carl Pasurka, Office of Policy, Planning and Evaluation, U.S. Environmental Protection Agency, Washington, D.C.

Table 2.4.1
Impact of Environmental Protection Regulation Upon the Current Account Balance

Study	Type of Model	Jurisdiction	Change in Current Account Balance
Chase Econometric Assoc. (1972)	macroeconometric	U.S.	-
D'Arge (1974)	small system	U.S.	+
Evans (1973)	macroeconometric, input-output	U.S.	-
Kalt (1988)	input-output	U.S.	-
O.E.C.D. (1985)	macroeconometric	Six OECD	+
Robison (1988)	input-output	U.S.	-
Tobey (1990)	small system	U.S.	nil
Walter (1973)	small system	U.S.	-

Market Share

Hypothesis #1 Market Share Decreases if Competitors Face Less Stringent Regulations

Industry representatives often claim that their firms or sectors are subject to more stringent environmental regulations than their competitors. More stringent regulations impose higher compliance costs. This makes it more difficult for such firms to compete on the basis of price, thereby reducing their market share.

Hypothesis #2 Market Share Decreases if Competitors Are Able to Abate More Cheaply

Even if firms or sectors are subject to the same environmental protection requirements, some firms or sectors may be able to comply with regulations more cheaply than others. Those with higher abatement costs may lose market share due to their reduced ability to compete on the basis of price.

Empirical Evidence

The following represent the only known studies which have examined the impact of environmental regulations upon market shares.

- Pashigian (1984) examined by size of firm the regulatory burden imposed by U.S. environmental regulations. A single-equation regression approach yielded the result that regulations decreased the market share of smaller firms, while the market share of larger firms was increased. Since market share is a measure of competitiveness, it can be concluded that regulations decreased the competitiveness of smaller firms relative to larger competitors. Of course, this study implies nothing about the *international* competitiveness of U.S. firms.

- Robison (1988) examined the impact of U.S. environmental regulations upon the share of total U.S. exports and imports accounted for by each of 78 U.S. industrial sectors. It was found that the composition of U.S. trade had shifted, with the shares of high-abatement-cost industries decreasing relative to low-abatement-cost industries. Thus, environmental regulations did reduce the international competitiveness of some U.S. industries more than others.

Indices of Determinants of Competitiveness

Competitiveness indices are functions of individual determinants. An index will change if environmental protection measures affect any component of the index. Examining this possibility is the second approach taken to identifying hypothesized transmission channels (see below).

Empirical Evidence

No literature was found relating environmental regulations to fluctuations in competitiveness indices. Of course, many studies examine regulatory impacts upon components of competitiveness indices. In particular, the effects upon productivity have been well-documented in the United States. This is discussed in detail later in this report.

Relative Profitability

Hypothesis #1 *Relative Profitability Decreases if Productivity Decreases as a Result of Environmental Regulations*

There are many factors which influence firms' profit rates. In the long-run, productivity is believed to be one of the most significant factors. If environmental regulations decrease a firm's productivity, that firm's profitability is expected to decline relative to the profitability of its competitors.

Of course, the converse of the hypothesis may also be true. If environmental regulations increase a firm's productivity, then its profitability relative to competitors may increase. The impact of environmental regulations upon productivity is discussed in detail later in the report.

Empirical Evidence

Little empirical work on profitability and environmental regulations was found. Many regulatory impact analyses compare expected compliance costs with profits to assess whether or not firms can absorb compliance costs. However, this analysis is conducted on a firm-by-firm and is not generally used for comparative purposes. No studies of regulatory impacts on *relative* profitability were found. These would require *comparing* regulatory impacts on the profitability of firms in different jurisdictions.

Relative Unit Costs

Hypothesis #1 Relative Unit Costs Increase If Competitors Face Less Stringent Environmental Regulations

Assuming marginal abatement and control costs are fairly constant across firms, firms subject to more stringent regulations incur greater compliance costs than firms facing less stringent regulations. If the firms' output levels are comparable, then unit costs will increase more for firms facing the most stringent regulations relative to the unit costs of competitors. Higher relative unit costs reduce firms' ability to compete on the basis of price.

Hypothesis #2 Relative Unit Costs Increase If Competitors Can Abate More Cheaply

In practice, marginal abatement and control costs can vary among regulated firms.[3] Therefore, even if all firms face regulations of equal stringency, total compliance costs will be higher for some firms than others. Firms with high marginal abatement costs will experience larger increases in unit costs than firms of comparable output levels with lower marginal abatement costs. Again, higher relative unit costs reduce firms ability to compete on the basis of price.

Empirical Evidence

No major studies were found which estimate the changes in relative unit costs due to environmental protection regulations.

Relative Productivity

There exists many hypothesized channels through which environmental protection measures may impact on productivity. These are discussed in detail in the next chapter of the report.

Summary of Approach #1

Numerous hypotheses regarding the impacts of environmental regulations on competitiveness are suggested by examining each measure of competitiveness. Several conclusions are evident.

- No empirical estimates are available of the impacts of environmental protection measures and three of the competitiveness measures (competitiveness indices, relative profitability and relative unit costs).
- The hypothesized transmission channels identified under relative profitability and relative unit costs are closely related to productivity.

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[3] For examples, see the economic assessments of MISA draft regulations produced by the Ontario Ministry of the Environment.

Table 2.4.2
WCR Competitiveness Determinants Most Likely to Be Influenced by Environmental Protection Regulations

Factor I	***Domestic Economic Strength***
·	Domestic Savings
·	Domestic Investment
·	Domestic Output
·	Inflation
·	Retail Sales
·	Production of Intermediate Inputs (Steel, Chemicals, Cement, etc.)
Factor II	***Internationalization***
·	Terms of Trade
·	Current Account Balance
·	Exchange Rate
·	Foreign Investment
Factor III	***Government***
·	Regulatory Environment
·	Non-Productive Investment
·	Environmental Protection
Factor IV	***Finance***
·	Interest Rates
·	Price/Earnings Ratio
Factor V	***Infrastructure***
·	Production of Key Minerals
·	Production and Cost of Key Energy Sources
·	Recycling of Resources
Factor VI	***Management***
·	Plant and Equipment Maintenance and Reinvestment
·	Overall Productivity
·	Manufacturing Unit Labour Costs
·	Competitive Pricing
Factor VII	***Science and Technology***
·	R&D Expenditures
Factor VIII	***People***
·	Life Expectancy

- Two studies have examined the impact of environmental protection regulations on market share. Neither of these estimates the impact on *international* market shares.

- The current account balance does not perform well in estimating the regulatory impact upon competitiveness. Regulations affect the current account balance in ways which do not reflect the original definitions of competitiveness.

Approach #2 Transmission Channels and Determinants of Competitiveness

The first approach to identifying possible transmission channels through which environmental protection measures impact on competitiveness was to examine the ways in which environmental protection measures influence directly *measures* of competitiveness. The second approach is to assess how environmental protection measures may influence the *determinants* of competitiveness.

The *World Competitiveness Report* (World Economic Forum, 1991) represents the most exhaustive compilation of the determinants of competitiveness. Three hundred and thirty determinants are incorporated into the WCR competitiveness index. These are listed in Appendix B.

From this list, we extracted the determinants that environmental protection measures would be most likely to influence. These determinants, presented in Table 2.4.2, were selected according to the project's team knowledge of the impacts of environmental regulations and the empirical estimates of the regulatory impacts reviewed for this study.

For each of the determinants that may be affected by environmental protection measures, it is possible to hypothesize numerous transmission channels. For example, the WCR includes interest rates as a determinant of competitiveness. It is possible that environmental protection regulations measures influence interest rates in at least the following ways.

- Demand for capital may increase if firms require loans to finance expenditures on pollution control equipment to comply with environmental regulations. This increased demand for capital would tend to increase interest rates.

- Firms may choose to comply with environmental regulations by switching to more capital intensive production processes. The resulting increases in the demand for finance capital would tend to increase interest rates.

- If environmental regulations result in plant closings, unemployment may increase. The resulting decline in personal savings would tend to increase interest rates.

- If more stringent environmental regulations are placed on new pollution sources, firms are encouraged to reduce investment in new plants and to continue to operate old plants. This reduction in the demand for capital would tend to decrease interest rates.

- If environmental regulations result in a thriving environmental protection industry that generates employment, personal savings may increase, thereby exerting downward pressure on interest rates.

This one example illustrates the following problems inherent in Approach #2.

- There is a large number of determinants of competitiveness that may be affected by environmental protection measures.
- Environmental regulations may influence each determinant through numerous transmission channels.
- It is not possible to unambiguously determine the direction of potential regulatory impacts on each determinant.
- Little or no evidence exists to indicate whether or not the hypothesized transmission channels result in major impacts on competitiveness.

Summary of Approach #2

Attempting to compile hypothesized transmission channels by assessing whether the determinants of competitiveness may be affected by environmental protection measures illustrates the complexity of analysing competitiveness. The WCR index includes 330 diverse determinants of competitiveness. It is possible to hypothesize literally hundreds of transmission channels. Many hypothesized channels are so complex as to justify an individual study.

2.5 Conclusions

The discussion has clearly shown that the lack of a widely accepted working definition of competitiveness is a serious impediment to applied research. Competitiveness remains at a conceptual stage.

Our review of the determinants of competitiveness also revealed many analytical problems. Since competitiveness is poorly defined, its determinants are also unfocused. They range from plant-level management practices to aggregate economic variables such as GDP and the exchange rate. This diversity may indicate that, either the current understanding of competitiveness is very poor, or the concept itself is so broad as to defy rigorous analysis.

Until further development of the concept of competitiveness occurs, empirical researchers must continue to find ways of focusing on certain aspects of competitiveness issues. For the following reasons, it appears that the most feasible and widely accepted method of doing this is to use relative productivity as a working measure of competitiveness.

- Relative productivity is recognized as one of the most important determinants of competitiveness. Many prominent analysts assert that the bottomline of competitiveness is relative productivity.

- Little or no analysis has been conducted on regulatory impacts on market share, relative unit costs and relative profitability.

- Some empirical evidence examines regulatory impacts on the current account balance of other countries, primarily the U.S. Macroeconometric models, input-output models and formal small system models are the most common analytical instruments for generating these estimates. Use of such models are beyond the scope of this study.

- The current account balance is an ambiguous measure of competitiveness. Environmental regulations can result in changes to the current account balance without representing changes in competitiveness.

- One of the goals of this study is to examine the impact of environmental protection measures on the competitiveness of Ontario industry. Therefore, the empirical assessment of regulatory impacts on Ontario industry must be comparable to estimated impacts in other jurisdictions. As we shall see in the next chapter, regulatory impacts on the productivity of Canadian competitors have been estimated by numerous analysts.

For these reasons, relative productivity was selected as the preferred measure of competitiveness for this study. Chapter 3 examines productivity in more depth.

3.0 Productivity and Environmental Regulations

Summary

Productivity may be broadly defined as a measure of output produced per unit of inputs employed. Much consensus exists on the general approach to calculating productivity measures. However, for any specific application, technical issues arise, such as the choices between single-factor productivity (e.g., labour productivity) and total factor productivity, measuring output as real output or real value added, and various methods of aggregating inputs. Nonetheless, well-developed practices exist to measure productivity at the national, industry, firm and plant levels.

Environmental regulations may affect productivity through many diverse channels. For example, regulatory impacts on productivity could occur through: altering economies of scale, capital turnover rates and the issues to which R&D funds are devoted; diverting inputs away from "productive" uses; generating off-setting benefits from material recovery; and raising the prices of intermediate goods. Among these hypotheses are positive impacts, negative impacts and contradictory impacts.

Environmental regulations have been widely examined as a possible reason for the slowdown in productivity growth occurring in many industrialized nations since the early 1970s. The empirical literature includes many tests of individual hypotheses and, more commonly, estimates of the net impact on productivity growth resulting from many hypotheses. Unfortunately, it is difficult to detect a consensus among these studies. Results vary significantly depending on the analytical framework and the data employed in the study.

The purpose of this chapter is to lay the foundations for an empirical analysis of the effects on productivity of Ontario environmental protection regulations. In section 3.1, we provide an overview of the concept of productivity, including a basic definition and a discussion of its general determinants. Section 3.2 follows with a detailed examination of productivity measurement issues relevant to all levels of analysis: plant, firm, industry and macroeconomic. Since further issues arise regarding plant and firm productivity, section 3.3 discusses productivity measures and indicators specific to these levels. Hypothesized transmission channels whereby environmental protection regulations may affect productivity are presented in section 3.4. Conclusions are presented in section 3.5.

3.1 Productivity Defined

Productivity may be broadly defined as a measure of output produced per unit of inputs employed. Inputs, such as labour, capital, energy and materials, are combined in plants to produce output. Productivity is a measure of the efficiency with which output is produced from inputs.

Output, while seemingly straightforward, becomes more complicated when discussing the effects of environmental regulations upon productivity. To begin, output refers to output which passes through a market. The production of contaminants, therefore, is not included in output. However, if a firm responds to environmental regulations by transforming "waste" by-products into a marketable good, this activity is encompassed by measured output.

It will be useful later to classify inputs by use. *Productive inputs* are those factors of production which are devoted to producing measured output. They are distinguished from *pollution abatement and control (PAC) inputs* which are those inputs attributed to pollution control activities. As we shall see later, productivity analysis is hampered by the fact that these two categories of inputs are not always distinct. For example, sometimes inputs attributed to pollution abatement and control can contribute to marketable output.

Productivity occupies a position of prominence among descriptive characteristics of the production process. This is due to the belief that productivity is a primary determinant of economic growth. For example, Denison (1974) estimated that 47% of the growth in U.S. real national income between 1929 and 1969 was due to productivity increases. A second landmark study, Jorgenson and Christainsen (1973), attributes 43% of the growth in U.S. gross private domestic product to productivity advances. Hence, productivity enhancement is thought to be essential to improving standards of living.

3.2 General Measures of Productivity

A large body of literature discusses the complexities of productivity measurement. In fact, entire books are devoted to the measurement of individual components of productivity. As an entry into this work, Sharpe (1990) provides a useful overview of the components of productivity measures. Exhibit 3.2.1 demonstrates how a productivity measure may be built using a variety of variables. Many important issues arise at each stage. Discussion of the most important of these issues will begin with an examination of the ways in which productivity measures are constructed from individual variables. Following that, the measurement of each component variable will be discussed.

Construction of Productivity Measures

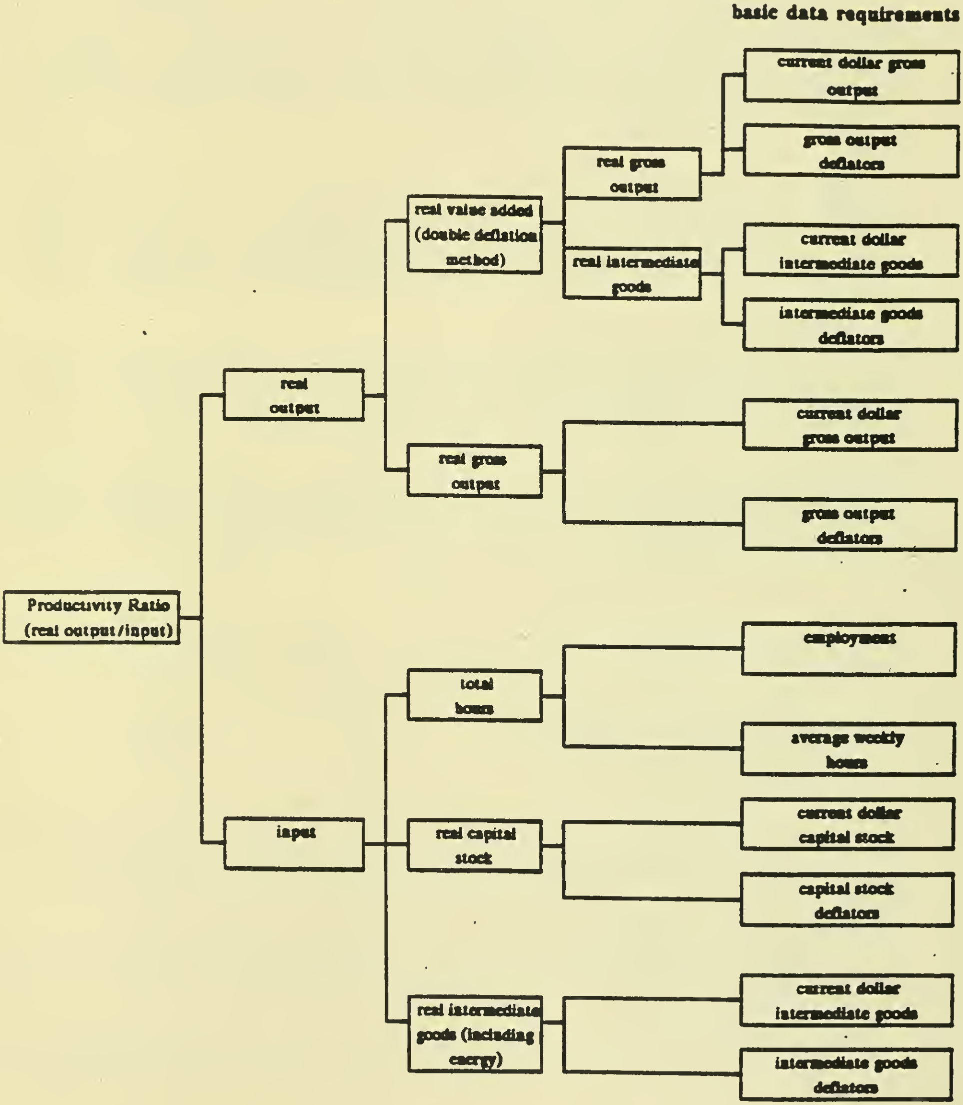
At a conceptual level, productivity is usually denominated in physical units. It is physical output per unit of physical inputs which captures the efficiency of the production process and which is of primary interest to most productivity analysts.

Unfortunately, an immediate problem arises in employing this definition. Inputs are not denominated in common units, but rather are denominated as number of hours worked, kilowatts of energy consumed, etc. Therefore, they cannot be directly aggregated into total factor input.

Two approaches are used in dealing with this problem. First, many analysts have chosen to study single factor productivity, such as labour productivity or capital productivity. Second, others have attempted to transform inputs into a common unit of measurement and then aggregate these measures. The strengths, weaknesses and other relevant issues of each approach are discussed below.

Exhibit 3.2.1

Building Blocks of Productivity Measurement


basic data requirements
Productivity Ratio (real output/input)
real output
input
real value added (double deflation method)
real gross output
real intermediate goods
current dollar gross output
gross output deflators
current dollar intermediate goods
intermediate goods deflators
real gross output
current dollar gross output
gross output deflators
total hours
employment
average weekly hours
real capital stock
current dollar capital stock
capital stock deflators
real intermediate goods (including energy)
current dollar intermediate goods
intermediate goods deflators

Source: Sharpe (1990), Figure 1

Total Factor Productivity versus Single Factor Productivity

The differences between total factor and single factor measures of productivity is in the definition of the denominator. Total factor productivity (TFP) is defined as output per unit of an aggregate index of all inputs used in the production proces.[4] Alternatively, single factor productivity (SFP) is defined as output per unit of an individual input, such as labour or capital. Due to the relative ease in measuring labour inputs, labour productivity is the most commonly used type of SFP. Capital productivity has proved more difficult to calculate satisfactorily, due to conceptual and practical problems in measuring capital inputs. Some analysis has focused upon energy productivity due to the hypothesized correlation between capital inputs and energy inputs (Siegel, 1981).

Regardless of whether a TFP or SFP approach is taken, care must be taken in the interpretation of productivity measures. For example, an increase in labour productivity cannot be unambiguously attributed to increased efficiency in the use of employees. This would only be the case if the output measure included only the contribution to output made by labour. Despite such difficulties many analysts maintain that the SFP approach is useful. Measures of productivity must be tailored to address the questions of interest.

Aggregation of Inputs

A second issue in constructing TFP measures is how to aggregate inputs which are measured in diverse units such as person hours worked and dollar value of capital service flows. Even SFP measures may require aggregation over different types of capital or labour, for example.

The obvious solution has been to value everything in dollar terms. Once monetized, inputs may be aggregated using several different methods. For highly theoretical reasons, most analysts adopt an aggregation method known as the Divisia Index.[5] According to the Divisia index, inputs are weighted by their share in total input costs:

$$\text{Total Factor Input} = c_k{*}K + c_l{*}L + c_e{*}E + c_m{*}M$$

where K, L, E and M denote expenditures on capital, labour, energy and material inputs respectively, and c_i = expenditures on input i, i = k, l, e, m, divided by total expenditures on all four inputs.

Measuring Components of Productivity

- Labour Inputs

  The physical quantity of labour inputs is perhaps the least contentious component of productivity measures (Panel to Review Productivity Statistics, 1979). Labour inputs may be denominated as number of employees or, more frequently, hours of labour employed. Government labour force surveys routinely collect labour data on number of employees and average weekly hours worked per employee. Thus, total number of person hours employed is easily calculated.

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[4] In practice, many productivity measures capture more than one, but less than all, inputs. Such measures are more accurately called Multi Factor Productivity. However, for simplicity, we continue to use the term Total Factor Productivity.

[5] See Sudit (1984) for a discussion of the advantages of the Divisia index over other aggregation methods.

Two approaches to aggregating labour inputs are available. The first approach merely adds all labour units, usually derived by multiplying number of workers and average hours worked. The second approach weights each unit of labour by its relative earnings, a measure of its relative contribution to output. When labour is monetized in order to aggregate across inputs, earnings or total wage bill (including benefits) provide ready measures of the monetary value of labour inputs employed.

Regardless of which aggregation technique is selected, this general approach to measuring labour inputs encounters difficulty in capturing some of the more detailed aspects of measuring labour input. First, data sources on labour inputs generally reflect the number of hours of *paid* work rather than the *actual* number of hours worked. Therefore, unpaid overtime is not included, while paid sick leave, for example, is included.

Second, the approach accounts for changes in the quality of labour inputs only if it is assumed that employees are paid according to their marginal productivities. In practice, the composition of the labour force along lines of occupation, industry, education, experience, age and sex have been used as proxies for labour quality (Kunze, 1979). If labour is not paid its marginal productivity, then measured labour inputs do not accurately reflect actual labour inputs.

Third, the approach assumes that output is unaffected by the proportions in which hours and number of workers are combined (Panel to Review Productivity Statistics, 1979).[6] For example, if paid equal wages, two workers employed for 40 hours per week each are assumed to produce the same output as one worker employed for 80 hours per week. The approach measures these two cases as equal labour inputs, even though labour effort may not be equal.

- Capital Inputs

The conceptually desirable measure of capital inputs is the flow of services derived from the real capital stock. Unlike labour inputs where the numbers of physical units employed are generally available, physical measures of the capital stock, such as number of machines of a given type, are rarely known. Hence, the capital stock is most often denominated in monetary terms. It can be calculated by summing the book value of capital in place or by the perpetual inventory method of accumulating investments over time allowing for retirement of capital after a given number of years.

Many thorny issues surround measurement of the capital stock. First, analysts must choose between using gross capital stocks or netting out depreciation. Although the book value of capital is depreciated, some argue that the annual output-producing capacity of capital goods may not decrease with age. For example, even though firms' accountants reduce annually the book value of each piece of equipment, the usefulness of individual pieces of equipment to the production process does not necessarily diminish. If this is true, the gross capital stock should be used rather than the net stock. Expert opinion, however, remains divided (Panel, 1979).

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[6] Hereafter referred to as Panel (1979).

Second, it has been argued that unused capital is not relevant in calculating capital inputs. Only utilized capital should be used in measuring capital services. Therefore, the capital stock should be multiplied by the capacity utilization rate to obtain the capital stock pertinent to productivity measurement. However, data on capacity utilization are often too unreliable to make adequate adjustments. Furthermore, other inputs such as labour and energy are highly correlated with the use of capital stocks, and so changes in utilization rates may be better considered an inherent aspect of capital efficiency. For example, underutilized capital stock is clearly inefficient and this inefficiency should be reflected in productivity. No consensus exists on the desirability of adjusting the capital stock for capacity utilization.

Once a suitable definition of the capital stock is chosen, the intangible flow of services from the stock is calculated by multiplying the real capital stock by a rate of return of capital. Since capital services *per se* do not pass through a market, this rate of return must be estimated. Choice of rate of return has also been the subject of much controversy. The most prominent debate has been between those who advocate using a gross rate of return and those advocating use of a net rate of return. Current consensus appears to favour gross rates of return since they represent the actual cash flow from the capital stock (Panel, 1979) or, in other words, output prices include the full (gross) cost of capital (Norsworthy et al., 1979).

- Intermediate Inputs

Intermediate inputs are generally defined as inputs bought from other firms, excluding capital expenditures (Sudit, 1984). Intermediate inputs then include raw materials such as coal, semi-finished goods that require further manufacturing, and energy.

Measuring intermediate inputs is relatively free from conceptual issues. Expenditures on materials and energy are widely available for industrial sectors.

- Output

Two major approaches exist to measuring output. The first uses real output, while the second uses real value added defined as real output less real intermediate inputs. Each output measure has implications for how productivity should be defined.

First, real value added measures the contribution of labour and capital inputs to production. It encompasses the costs of labour, capital depreciation, taxes and profits only (Greenberg, 1973). Since output is net of intermediate inputs, TFP measures should also exclude intermediate inputs from the denominator, as follows:

$$\begin{aligned} TFP &= \frac{\text{Output - Intermediate Inputs}}{c_k(\text{Capital Services}) + c_l(\text{Labour})} \qquad (1) \\ &= \frac{\text{Value Added}}{c_k(\text{Capital Services}) + c_l(\text{Labour})} \end{aligned}$$

where c_k and c_l are the shares of total cost accounted for by capital services and labour respectively. Note that output and inputs are all stated in real terms.

Alternatively, real output measures the contributions to production of labour, capital *and* intermediate inputs. In this case TFP measures would be constructed as:

$$\text{TFP} = \frac{\text{Output}}{c_k(\text{Capital Services}) + c_l(\text{Labour}) + c_e(\text{Energy}) + c_m(\text{Materials})} \qquad (2)$$

The output approach to productivity measurement is preferred by many since it models explicitly substitution possibilities between capital and labour inputs, on the one hand, and intermediate inputs on the other (Panel, 1979). For example, suppose we adopt a value added measure of productivity (1). Substitution of extra material inputs for some capital inputs would tend to decrease both the numerator (value added) and the denominator (through capital services). The impact on output is indeterminant. However, using an output based productivity measure (2) would show explicitly a decrease in capital services, an increase in materials and the net effect on output.

Note that if real output is used rather than real value added, a second issue must be faced, namely the choice between gross output or net output. The debate over whether output should be measured net of replacement investment has been quite intense. However, a consensus seems to have emerged that use of gross output is preferable since the net approach implies that replacement investment could not have been diverted to other uses (Norsworthy et al., 1979).

Price Indices

As discussed above, the concept of productivity is a measure of the efficiency with which physical outputs are produced from physical inputs. In practice, however, inputs and outputs are usually translated into monetary units by multiplying input stocks by input prices.

Since these monetary values fluctuate with inflation, real values are more accurate measures of the physical inputs used. The consequences of failing to do so are clearly demonstrated by a simple example. If inflation was larger for output than inputs, then productivity measured as the ratio of nominal output to nominal inputs would rise independently of any changes in production efficiency. Therefore, unambiguous interpretation of changes in productivity measures would be impossible.

Unfortunately, difficulties arise since price indices used to deflate the value of outputs and inputs to constant dollars do not only reflect inflation. In addition, changes in price also result from changes in the quality of the good. Unfortunately, price indices are usually not disaggregated enough to distinguish between similar inputs and output and hence may also net out the effect of changes in the quality of outputs and inputs.

For example, through the process of education or training, workers may become more skilled and command higher wages. A price of labour index, however, may attribute this increase in wages to inflation rather than a change in labour quality. Use of this index to deflate labour inputs will underestimate labour inputs and, therefore, overestimate productivity. This type of bias is most troublesome in industries, such as computer manufacturing, in which input and output quality is changing rapidly (Sharpe, 1990).[7]

3.3 Measures and Indicators of Firm and Plant Productivity

The above discussion of general measurement issues are relevant to all levels of productivity analysis. However, there are additional considerations at highly disaggregated levels, namely individual plants and firms. We discuss these issues below.

Plant Productivity Measurement

The concept of productivity is perhaps most directly related to production plants. It is at this level that the notion of transforming physical inputs into physical outputs is most obvious.

Unfortunately, few studies of plant-level productivity are publicly available. Although there are examples of firms developing plant-level productivity measurement programs, these analyses are intimate aspects of their competitive strategies and hence are not open to public scrutiny.

The few plant-level productivity studies which are publicly available indicate that an "engineering approach" to measuring plant productivity may be most common (Takeuchi, 1984). Engineers collect data on physical inputs and outputs which allow for calculation of productivity measures. Linear programming techniques are sometimes used to model the production process.

Kopp and Smith (1981) provide an example of this type of analysis. Data are generated using process models constructed by engineers. Five models replicate different types of steel-manufacturing technology. The models provide least-cost input requirements for given levels of output. Constrained optimization experiments can be conducted by limiting values of certain inputs or by-products such as pollution emissions. Therefore, the models can produce least-cost production strategies for any level of pollution emission specified.

Several other productivity studies have been conducted using plant-level data obtained by special permission from firms.[8] Data provided to government statistical agencies typically include quantities of labour and intermediate inputs, capital expenditures and output levels. Confidentiality restrictions, however, prevent use of these data for purposes other than compiling aggregate statistics.

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[7] In essence, this problem results from aggregation across inputs. If a separate price index existed for each quality of input or output, no bias would result. Fortunately for this study, the industries which incur the largest costs to comply with environmental regulations produce goods and use inputs whose quality is relatively constant over time. Hence, this may not be a significant problem for this study.

[8] See, for example, Pittman (1981) and Sims and Smith (1983). These are discussed in further detail below.

These few studies indicate that measurement of plant productivity is as yet a highly undeveloped practice. Publicly available data do not typically allow estimation of productivity for individual plants. Of course, if a firm has only one plant, then plant productivity and firm productivity are one in the same. In these cases, the following discussion applies.

Firm Productivity Measurement

There is a small body of literature which attempts to measure productivity at the level of the firm.[9] In addition to dealing with general issues regarding productivity, the literature focuses upon how productivity measures may be derived from financial data contained in corporate annual reports or forms submitted to regulatory agencies.

Most of the variables used in constructing productivity measures have financial analogues. Table 3.3.1 summarizes the types of financial data related to each component of productivity measures. Further elaboration is provided below.

Table 3.3.1
Financial Measurement of Firm Productivity

Components of Productivity	Related Financial Variables
Labour Inputs	Employee Compensation including benefits Total Wage Bill Number of Employees
Capital Inputs	Fixed Assets at Book Value Cash, Notes and Accounts Receivable Investment in Fixed Assets Capital Expenses (depreciation, interest) Net Income
Intermediate Inputs	Expenditures on Raw Materials and Energy
Total Output	Revenues Sales Change in Output Inventories
Price Indices	None Available

Source: Revised from Sudit (1984), Table 1-1.

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[9] See Siegel (1980) for a review of case studies.

Before discussing financial proxies for each component of productivity measures, it must be stressed that using corporate financial data to measure productivity involves some theoretical difficulties. The major difficulty faced is the potential inadequacy of using *financial* data derived according to accounting definitions to measure a concept of *physical* efficiency, such as productivity.

To address this potential problem, the project consulting team held a workshop with accountants and economists specializing in productivity analysis. During this workshop, corporate annual reports were scrutinized for potential financial proxies for output, labour inputs, capital inputs and intermediates needed to measure productivity. The strengths and weaknesses of using financial proxies were evaluated. The discussion below summarizes the results from the workshop.

- Labour Inputs

  Similar to aggregate levels, measurement of firms' labour inputs are relatively untroublesome. Theoretically, the value of labour inputs are calculated by multiplying person hours worked for each job classification by the appropriate wage rate and summing. All other employee remuneration, such as bonuses, vacation pay and fringe benefits, should also be added.[10]

  Total employee compensation (sometimes called the total wage bill) found in many corporate annual reports provides an estimate of labour inputs. Strengths of this measure are that it includes all expenditures on labour input. Several weaknesses also exist. Comparison of productivity levels across firms or time using this measure assume that changes in wage rates reflect changes in labour quality or labour's contribution to output. In fact, wage rate differentials are also influenced by factors such as union strength and geographical location of plants (Sudit, 1984). At least conceptually, the influence of plant location on wage rates, however, may be netted out by weighting wage rates by relative cost of living indices.

  As an alternative measure of labour inputs, corporate annual reports often include number of employees (Pratten, 1976). This, however is a much rougher approximation of labour inputs since the time contributions of each employee is not provided. For example, the productivity of 200 part-time employees will be much different from an equal number of full-time employees if their status is not taken into account. Unless adjustments are made to net out the effects of changes in full-time/part-time employee status, estimated fluctuations in productivity may be biased. Unfortunately, corporate annual reports do not provide the information necessary to make such adjustments.

- Capital Inputs

  At one time, depreciation, the amount of capital consumed in the production process, has been used to approximate capital inputs (Craig and Harris, 1973). However, due to criticism that depreciation does not measure the flow of services from the capital stock, this variable is no longer used. Three approaches now exist to measuring capital inputs.

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[10] For an interesting exception, see Sherrard (1967). He estimates output per manhour employed for *each* job classification.

First, a rate of return can be applied to the book value of fixed assets (land, building and equipment) provided on corporate balance sheets. Unfortunately, the book value of fixed assets has several shortcomings as a measure of the capital stock. First, book values relate to the value calculated according to accounting principles. However, these may have little relation to the productive capacity of the capital goods. Second, little is known about the vintage of the fixed assets and therefore choice of appropriate rates of return is difficult. In addition to fixed assets, some companies treat financial assets such as cash, notes and accounts receivable as part of their capital stock (Ullman, 1981).

The second approach to measuring capital inputs applies a rate of return to estimates of the capital stock derived from investment expenditures. However, estimates of the capital stock using this approach can be sensitive to assumptions regarding capital life-span and depreciation rules.

Third, the residual approach defines return to capital as the value of output not accounted for by labour, energy and material inputs.[11] Productivity analysis commonly assumes that input and output markets are perfectly competitive. Under this assumption, output value is equal to the total returns to inputs and subtracting the costs of all non-capital inputs from the value of output yields the return to capital.

If either the first or second methods are employed, further problems arise. First, it is not obvious how leased capital should be treated (Panel, 1979). Second, since capacity utilization rates are not available at the level of the firm, no adjustments to the capital stock can be made to account for variations in the intensity of use of the capital stock.

Third, there is no obvious rate of return to estimate the flow of services obtained from the capital stock. Since this rate of return is a measure of the opportunity cost of capital, it incorporates the rate of depreciation, interest rate and capital gains. Unfortunately, reported depreciation is defined according to tax laws and accounting practices rather than accurately reflecting the amount of capital stock consumed.

- Intermediate Inputs

Firms report total operating expenses. These include expenditures on all inputs, including labour. Identification of intermediate expenses depends upon the degree to which firms disaggregate operating expenses. Some firms do not provide enough information to disentangle costs of intermediate inputs at all. Others include separate estimates of material and energy expenses. This is especially true in industries with large expenditures on one or two raw materials, such as crude oil for the petrochemical sector.

A measurement problem may occur if firms keep inventories of inputs. Ideally, intermediate inputs should measure those inputs actually used rather than input outlays that include inputs purchased but not used. However, if data on changes in inventories of intermediate inputs are unavailable, changes in inventories of intermediate inputs cannot be netted out.

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[11] See Denny et al. (1991a) for an example of the residual approach to capital stock measurement.

- Output

  Occasionally, some firms will provide physical measures of output, such as tonnes of newsprint or steel produced. These measures are ill-suited to multi-output firms since aggregation across multiple outputs requires common denomination (Gold, 1976). If the productivity of producing only one output was measured, difficulties may arise in allocating inputs to each product.

  More often, corporate annual reports provide a variety of monetary measures: sales, revenues, shipments, deliveries, etc. Since these measures reflect marketed output rather than production, changes in output inventories of finished and unfinished goods should also be included. Ideally, data should be disaggregated by product. Unfortunately, such data are often not available.

  Value added is determined by subtracting the value of intermediate inputs from the value of gross output. Intermediate inputs may include purchased services such as telephone, computing and advertising, as well as more traditional energy and raw materials (Siegel, 1981).

- Price Indices

  As described above, price deflators are required to calculate productivity changes over time. Since none exist specific to firms or plants, industry level price indices must be used. Deflators may be chosen by classifying firms by industry and then applying deflators derived from price indices relevant to that industry. Although this is a reasonable approach for single-output firms, it may distort productivity measures of multi-output firms. In these cases, each product line should be attributed to an industry if data allow.

In addition to issues regarding individual components of productivity, a number of more general concerns exist.

- Intertemporal Accounting Variations

  Common accounting practices have been altered over time. For example, measurement of capital inputs has been affected by changes of accounting practices relating to capital depreciation and leased equipment; measurement of labour inputs has been altered by changes to accepted treatment of employee fringe benefits; and measurement of output has been altered by changes to calculation of inventories. It is important to note, however, that time series compiled by government agencies at industry and macroeconomic levels have also undergone revision. Therefore, this problem is not unique to firm-level productivity measurement.

- Inter-Sectoral Accounting Variations

  Accounting practices have been shaped according to different needs of firms in each sector. Hence, cross-sector comparisons of productivity must take into consideration different definitions of component variables. Corrections for inconsistencies may require much work or may not be possible at all due to data constraints.

- Intra-Sectoral Accounting Variations

  Accounting practices have been tailored to meet the specific needs of individual firms. Though inconsistencies may not be as pronounced as between industries, if possible they should also be considered when comparing productivity across firms.

Financial Indicators of Firm Productivity

Statistics have been developed for the purposes of conveying firms' financial performances to suppliers of financial resources, namely investors and lenders. Two of these statistics, namely the rate of return to capital and unit costs, relate most directly to productivity.[12] Each is discussed below.

Rate of Return to Capital

The rate of return to capital provides an indication of trends in firm productivity. The key to the relationship is the underlying assumption -- standard in productivity analysis -- that firms operate in competitive factor markets. This ensures that factor returns are equal to their marginal productivities. Under this assumption, the rate of return to capital is somewhat akin to a measure of capital productivity. Appendix B illustrates more formally the theoretical underpinnings of this approach, as well as how it may be used to empirically estimate the effects of environmental regulations upon total factor productivity.

Unit Cost

Unit cost was originally a measure of the sum of expenditures on inputs required to produce one unit of physical output. This is clearly related to the inverse of productivity as measured by physical output per dollar of inputs.

However, Gold (1976) argues that unit cost does not provide an accurate measure of productivity. Gold writes:

> The original conception of unit cost as the sum of the outlays involved in producing a discrete unit of product is clearly inapplicable in modern large-scale manufacturing operations, which usually involve the simultaneous processing of many streams of components which are eventually assembled into a variety of products. Under such conditions, unit costs really represent the average ratio of total costs to total output over a given period rather than an average of the actual costs of each unit of output. (Gold, 1976:46).

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[12] Note that both of these were also cited above as measures of competitiveness. This emphasizes the importance of relative productivity to competitiveness.

This criticism is valid if the analyst is interested in estimating physical productivity by product line. However, environmental policy analysts are more likely interested in regulatory impacts on firms' activities as a whole rather than just one product line.

Gold also notes that other serious difficulties exist in interpreting unit cost as a measure of productivity. Specifically, unit of output is measured in physical terms. Yet firms rarely produce the exact same goods for long periods of time. For example, if a firm in the pulp and paper sector began manufacturing a slightly different grade of newsprint, then cost per tonne of newsprint may also change. This would not represent a shift in productivity, but rather would reflect the change in quality of output. Of course, this is similar to the potential bias introduced into productivity measures when price indices reflect quality improvements rather than inflation.

3.4 Hypothesized Transmission Channels and Empirical Evidence

The general relationship between environmental regulations and productivity may be conceptualized in two ways. These depend upon whether environmental degradation is thought of as resulting from the use of environmental resources as an input or the emission of contaminants as by-products. A discussion of each perspective follows.

Environmental Inputs

Environmental quality can be considered an input to the production process. Scarce environmental resources are used by firms. Firms derive disposal services from environmental resource inputs when water streams or air currents are used to carry away waste.

Environmental regulations place constraints upon firms' use of environmental inputs. This may occur in several ways. Standards limit the legal amount of this input firms may use. Economic instruments raise the price of the input.

When a constraint is placed upon firms' use of environmental inputs, firms' may respond by changing their input mix. Hence all input levels may be affected. Different amounts of inputs may be used or new inputs may be substituted altogether. Alternatively, firms may respond by changing their production process, using different technology or reducing output levels in order to limit the use of environmental inputs.

Waste By-Products

The second approach views environmental degradation as a consequence of wastes being produced jointly with desired outputs. Untreated, these outputs are emitted into the environment resulting in decreased ambient quality.

From this perspective, environmental regulations place a constraint upon firms outputs. By limiting the production of "environmental degradation" in the form of untreated pollutants, firms may respond by altering their entire production strategy, including both the amount and type of inputs used and the production process employed.

Regardless of whether environmental regulations are considered to be a direct constraint upon inputs or outputs, it is clear that all aspects of firms' behaviour may change when regulations are imposed. The impact of regulations may be felt in both input and output decisions. When these are aggregated across firms, important market feedback effects may occur. If the demand for certain inputs changes significantly, equilibrium input prices may change. If production costs increase substantially, changes in industry output or output price may also occur.

Changes to the quality of productive inputs and the uses for which they are employed, the production process and market feedbacks can all affect productivity measured at plant, firm, industry or macroeconomic levels.

Before turning to specific hypotheses regarding the effects of environmental regulations upon productivity, a few further notes are in order.

First, since there are many diverse hypotheses regarding the effects of environmental regulations upon productivity, a classification system has been developed. Each hypothesized transmission channel is based upon a behavioural model. If, for example, a particular hypothesis is based upon firm behaviour, then it is discussed in the section on firm level effects, even though it may also be relevant at more aggregated levels of economic activity.

Second, although this taxonomy is useful for classifying hypothesized effects, it is not conducive to summarizing the results of existing empirical research. Obviously effects based upon firm-level behaviour may be aggregated over firms. This implies that variables measuring industry behaviour may also change. In fact, due to data availability, most empirical research is conducted using industry-level data. However, it has been decided to review all empirical studies relating to each hypothesis regardless of the level of data which the study used.

Finally, unless otherwise stated, empirical estimates are for U.S. jurisdictions. This is where the bulk of the research on the industrial effects of environmental protection regulations has been undertaken.

Firm and Plant Level Hypotheses

Diversion of Inputs

Hypothesis #1 *Productivity Decreases If Environmental Regulations Force Firms to Devote Limited Inputs to Pollution Control Activities that Do Not Contribute to Marketable Output*

In order to comply with environmental regulations, firms may devote some of their inputs to pollution control activities. These diverted inputs encompass all factors used in responding to environmental regulations. For example, diverted labour inputs can include technicians to operate pollution control equipment and machinery, engineers to install pollution control facilities, lab workers to test samples, office staff to file reports, consult with regulators, and lobby legislators, etc. Machinery and equipment, such as air emission scrubbers, energy to run pollution control equipment and machinery, and materials also represent diverted inputs.

To the extent that these inputs do not contribute to output, the quantity of inputs required to produce a given level of output will increase. Therefore, productivity is expected to decline.

The hypothesis that environmental regulations divert inputs from productive activities to pollution control activities, which do not contribute to output, underlies many studies of the impacts of environmental regulations. For example, it is *assumed* that pollution control inputs fully displace productive inputs in the following analytical frameworks.

- Growth accounting studies usually use capital costs as their only measure of the impact of environmental regulations. This investment in control technology is assumed to displace investment in productive capital on a dollar-for-dollar basis.

- Input-output studies, due to their rich sectoral detail, generally encompass a greater measure of the input requirements of environmental regulations. The assumption of fixed-proportion production technology, however, implies that these input requirements are assumed to be non-productive and are merely subtracted from the base-case input levels.

- Macroeconometric models are used to estimate the impact of environmental regulations by deleting investment for pollution control purposes from the capital stock.

- Financial impact analysis makes use of a variety of ratios to predict the impact of environmental regulations. Input diversion is inherent in the interpretation of ratios, such as regulatory capital costs over total capital expenditures, as the percent reduction in inputs available for use in the production process.

Table 3.4.1 provides a summary of major growth accounting studies which examine the productivity effects of environmental regulations under the *assumption* of full diversion. Note that none of the growth accounting studies reported in the table are actually estimated at the firm or industry level even though the hypothesis is based upon a model of firm behaviour.

A very important step in productivity analysis has been the development of two frameworks to *estimate* empirically the extent to which input diversion occurs on a dollar-for-dollar basis (as is assumed in the models above). The first framework involves estimating production or cost functions which model the production process explicitly. The second framework consists of single-equation regression analysis with productivity as the dependent variable and a measure of regulatory burden as a determinant.[13] Table 3.4.2 summarizes the results of these studies.

It is important to realize that the studies in Table 3.4.2 do not explain *why* productivity is affected by regulations in the estimated magnitudes. The studies merely estimate the correlation without attributing the impact to a specific transmission channel.

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[13] The use of the term single-equation regression is consistent with a number of survey articles found in the literature review. Unfortunately, it may be confusing. Although most often cost/production functions are estimated as a system of equations, it is possible to estimate them as single equations. The framework labelled "single-equation regression" is defined quite specifically as functions relating productivity to a list of ad hoc determinants.

Table 3.4.1
Impact of Environmental Regulations Upon Productivity Under the Assumption of Full Input Diversion

Study	Analytic Framework	Aggregate Economy[1]	Productivity Measure	Inputs Diverted	Time Period	Percentage Impact on Annual Productivity Growth Rate
Conrad and Morrison (1989)	growth accounting	U.S. Canada Germany	net output per unit of labour and capital inputs	capital	1972-1980 1972-1980 1972-1980	-0.20 -0.06 -0.14
Denison (1984)	growth accounting	U.S.	non-residential business income per person employed	capital labour	1969-1973 1973-1976 1975-1978	-0.05 -0.22 -0.08
Farber, Dreiting and Rutledge (1984)	growth accounting	U.S.	non-farm output per person hour	all	1972-1984	-0.09
Kutscher, Mark and Norsworthy (1977)	growth accounting	U.S.	non-farm output per person hour	all	1966-1973	-0.10
Norsworthy, Harper and Kunze (1979)	growth accounting	U.S.	non-farm output per person hour	capital	1973-1978	-0.09
		U.S.	manufacturing output per person hour	capital	1973-1978	0.19

Note:

1. All studies were conducted at the macroeconomic level

Table 3.4.2
Impact of Environmental Protection Regulations Upon Productivity Growth Estimated from a Single-Equation Regression Framework

Study	Analytic Framework	Productivity Measure	Time Period	Economic Sector	Percentage Impact on Annual Productivity Growth Rate
Gray (1987)	single-equation regression	total factor productivity	1973-1978	manufacturing	-0.69
Haveman and Christainsen (1981)	single-equation regression	labour productivity	1958-1965 1965-1973 1973-1977	manufacturing	0.0 to -0.1 -0.1 to -0.3 -0.2 to -0.3
Siegel (1979)	single-equation regression	non-farm output per person hour	1967-1973 1973-1979	non-farm	-0.10 0.00
Thurow (1980)	single-equation regression	business output per person hour	1973-1978	business	-0.20

Capital Efficiency

Hypothesis #1 Productivity Decreases If Old Source/New Source Distinctions Retard Capital Turnover

Many environmental regulations are more stringent for new production units than for other units in the same industry. This old source/new source distinction provides firms with incentive to continue using old capital. Therefore, the lifespan of capital is effectively lengthened by regulations which discriminate between "old" and "new" pollution sources, and the capital turnover rate is reduced (Christainsen and Tietenberg, 1985; Crandall, 1981).

New capital is generally more efficient than old capital since new capital may embody technological progress. Therefore, if environmental regulations retard capital turnover, the efficiency of the capital stock will be reduced and productivity will decline.

Hypothesis #2 Productivity Increases If Environmental Regulations Quicken Capital Turnover

Environmental regulations may increase the speed of capital turnover (Boyd and Uri, 1991). When confronted with binding regulations, firms may choose to invest in new production capital which not only reduces pollution emissions but is also more efficient. By increasing the rate at which new capital is brought online, environmental regulations would increase the efficiency of the capital stock and thus raise productivity.

Empirical Evidence

No studies were found that estimated the extent to which turnover of production capital is affected by environmental protection measures. Indeed, theoretical frameworks with which these hypotheses may be tested remain undeveloped.

Input Substitution

Hypothesis #1 Productivity Decreases if Environmental Regulations Cause Firms to Switch to More Expensive or Less Efficient Materials or Energy Sources

Firms' responses to environmental regulations may not be as simple as using inputs specifically designed for pollution control. Rather the placing of a constraint upon one input (waste disposal in the environment) or output (untreated waste by-products) may affect the productive inputs used as well. This is clearly the case when firms comply with regulations by altering their production process, recycling waste by-products, or reformulating their product.

This hypothesis can be termed the input substitution hypothesis. Environmental goals may be achieved through altering productive inputs since there may be some substitutability between productive inputs and pollution control inputs. Although to some extent this may appear to be a semantic problem, the classification of inputs along these lines is inherent in many analytic frameworks available to study productivity. For example, the diversion hypothesis relies upon a strict dichotomy of inputs into productive and pollution control purposes.

Estimation of production or cost functions has provided the traditional approach to measuring elasticities of input substitution. However, only recently has the approach been applied to issues of environmental regulation. Exhibit 3.4.3 summarizes the estimated productivity impacts of environmental regulations using the production/cost function framework.

In addition to the studies in Exhibit 3.4.3, Kopp and Smith (1981) examine whether environmental regulations result in changes to input requirements other than pollution control capital and labour. Estimation of cost functions for three types of steel smelting plants uses "pseudo data" generated by a process-analysis sub-model.

Kopp and Smith (1981) find that environmental regulations have significant effects upon productive inputs. In particular, they find that firms respond to environmental regulations by substituting some productive inputs for other productive inputs. This implies that measures of single factor productivity may seriously underestimate the effects of regulations upon industrial productivity.

R&D Expenditures Hypotheses

Hypothesis #1 Productivity Decreases If Environmental Regulations Divert R&D from Process Innovation

Some evidence has attributed the slowdown in productivity growth to changes in the magnitude of R&D expenditures.[14] Griliches (1979), however, has suggested that there has also been a "collapse" in the productivity of R&D, that is R&D expenditures are also not producing as big a bang for the buck as they once did. Environmental protection regulations may force some firms to devote R&D efforts, not to process innovation and product redesign, but rather to developing waste treatment technology. Such diversion of R&D would reduce the productivity increases resulting from each dollar spent on R&D activities. Magat (1978, 1979) added environmental protection activities to theoretical models of technological advance and obtained this theoretical result.

Hypothesis #2 Productivity Increases If Pollution Control R&D Results in Cost Saving Process Innovation and Development of Marketable Products

R&D devoted to compliance activities may result in cost-saving process innovation or the development of marketable products. Since environmental regulations may force firms to examine aspects of their products or production process not normally emphasized, the "diverted" R&D expenditures may result in new products or production processes which result in, not only fewer waste by-products, but also reductions in production costs and/or discovery of marketable products. This would tend to increase productivity.

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[14] The evidence regarding the importance of R&D to the productivity slowdown is mixed. In a survey article, Griliches (1988) concludes that the effect is likely quite small relative to the magnitude of the decline.

Table 3.4.3

Impact of Environmental Protection Regulations Upon Productivity Growth Estimated from a Production/Cost Function Framework

Study	Analytic Framework	Productivity Measure	Time Period	Economic Sector	Percentage Impact on Annual Productivity Growth Rate	
					Capital	Labour
Barbera and McConnell (1986)	production function	single factor productivity (both capital and labour)	1973-1980	paper	0.00	0.50
				chemicals	-0.69	-0.35
				stone/clay/glass	-0.82	-1.18
				primary metals	-0.77	-0.55
Barbera and McConnell (1990)	cost function	total factor productivity	1960-1970 compared to 1970-1980	paper	-0.12	
				chemicals	-0.18	
				stone/clay/glass	-0.10	
				iron and steel	-0.15	
				non-ferrous metals	-0.08	
Gollop and Roberts (1983)	cost function	total factor productivity	1973-1979	electric utilities	-0.59	
Sims and Smith (1983)	cost function	total factor productivity	1971-1980	Cdn. brewing	-1.60	

We present four hypotheses regarding the link between environmental regulations and economies of scale. The final impact on productivity will depend on the relationship between economies of scale and productivity. For example, if in a particular industry higher productivity is obtained at higher economies of scale *and* if environmental regulations encourage firms to operate at higher output levels, then environmental regulations would tend to increase productivity.

Hypothesis #1 If Regulations Act as an Entry Barrier, Economies of Scale May Increase

Environmental regulations may act as a barrier by increasing costs of entry to new firms wishing to enter an industry.[18] Entry costs will rise as a result of environmental regulations if regulations require firms to undertake costly pollution control programs. This in turn may prevent firm entry if potential entrants have limited start-up capital or if a larger initial market share would have to be "pirated" from existing firms in order to make entry profitable (Pittman, 1981). Since firms often expand into new industries on the basis of innovations in products or production processes, regulations may also serve as an entry barrier if, as discussed above, regulations reduce the returns to R&D (Davies, 1983).

Hypothesis #2 If Economies of Scale Exist in Control Activities, Economies of Scale May Increase

The second hypothesis holds that economies of scale may exist in pollution control activities. For example, if control requires a large fixed cost for end-of pipe treatment facilities which is invariant to waste volume, then plants which operate at high output levels will have lower abatement costs per unit of output. This would increase plants' optimal output levels and thus change economies of scale in production activities.[19] It has been noted, however, that this effect may be offset if regulators tend to concentrate enforcement on larger firms (Christainsen and Tietenberg, 1985).

Some empirical evidence suggests that there are economies of scale in pollution control. For example, Hanke and Gutmanis (1975) found that, for both private and public wastewater treatment plants, the treatment cost per unit of wastewater declined as more water was treated. Similar economies of scale were found for in-plant process changes for fruit and vegetable processing plants. Kohn (1988) cites further evidence of economies of scale in abatement activities. The implications of these findings for general economies of scale is unknown.

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[18] In their most extreme form, environmental regulations may prohibit firm entry if new plants increase pollutant emissions at all. This might be the case if a potential entrant would increase regional emissions beyond levels allowed under U.S. Prevention of Significant Deterioration (PSD) regulations.

[19] Of course, changes in plants' output levels are dependent upon additional market factors. For example, increased output levels at the plant level may necessitate: (i) growing demand, despite possible rises in output price due to control costs; or (ii) the exit of plants not able to take advantage of these economies of scale, allowing demand to be met by fewer suppliers.

Hypothesis #3 If Firms with Low Control Costs Increase Market Share, Economies of Scale May Increase

The third hypothesis results from the fact that environmental regulations do not impose the same pollution control costs per unit of output across firms (Pashigian, 1984).[20] This results in increased competitiveness for firms with low control costs relative to firms with high control costs. Hence the market share and output of low-cost firms may increase and change the level of economies of scale present within that firm.

Hypothesis #4 If Emissions Per Unit of Output Increase with Output Levels, Economies of Scale May Decrease

Kohn (1986, 1988) offers a fourth hypothesis. In examining emissions per unit of output produced by diesel-powered generators in vessels, he finds evidence that they first decline as output increases and then increase with output. Once regulations make it costly to produce uncontrolled pollutants, output can be altered to take advantage of changes in emissions per unit of output. This shift in optimal output level could result in changes to economies of scale.

Empirical Evidence

No empirical work was found relating these individual hypotheses to the actual impact of environmental regulations upon economies of scale. Two studies, however, do test whether or not pollution control expenditures are related to changes in economies of scale. First, Pittman (1981) estimated a translog production function for a set of U.S. pulp and paper plants and found a strong, positive correlation between scale economies and pollution control intensity. Hence he concluded that "[waste] treatment requirements increase the minimum efficient size of plant, thus increasing barriers to entry and exacerbating any lack of competition in the industry."

Second, Pashigian (1984), using a single-equation regression framework, found that environmental regulations were responsible for an increase in average plant size across 319 industries. His results, however, have been challenged by Evans (1986).

Given that Pitmann studied only one industrial sector and that Pashigian's conclusions have been disputed, there are no general conclusions which can be drawn regarding the effects of environmental regulations upon the economies of scale in regulated industries, and the consequences that they have for productivity.

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[20] This does not imply that the regulator *should* attempt to equate average control costs per unit of output across firms. Clearly this may violate first-order efficiency conditions: equal marginal abatement costs across pollutant sources.

Marketable Output Hypotheses

Hypothesis #1 Productivity Increases If Environmental Regulations Result in Waste Recovery for Sale to Other Industries

One compliance strategy available to regulated firms is to reduce waste by recovering and recycling. In addition to meeting regulatory requirements, this could generate revenues from the sale of by-products. This revenue could partially or wholly offset compliance costs, thereby mitigating negative regulatory impacts on productivity.

Empirical Evidence

Much anecdotal evidence exists that some firms have adopted this strategy, including the following examples.

- Dow Chemical developed saleable ferric chloride from steelmaker's waste dust (Campbell and Glenn, 1982).
- Westvaco began converting its mill wastes into chemicals, eventually establishing a chemical products subsidiary which turns former waste by-products into chemical sales worth $45 million in 1980 (Royston, 1980).

Anecdotal evidence such as this has yet to be analyzed in a rigorous manner. Although it is clear that environmental regulations may affect output, productivity studies do not attribute these output fluctuations to the regulations. Care is taken in estimating the input requirements of environmental regulations, but the same effort is not taken to determine output changes. To the extent that these increases in output exist and are ignored, estimates of any adverse impact of environmental regulations upon productivity will be overstated.

Macroeconomic Level Hypotheses

Output Mix Hypotheses

Hypothesis #1 Productivity Increases If Environmental Regulations Encourage Transfer of Resources from Low Productivity Industries to High Productivity Industries

Changes in the allocation of resources is a commonly examined determinant of productivity for the economy as a whole. For example, the impact upon productivity of shifts from manufacturing to service industries is often examined. Similarly, the effects of shifts from farm to non-farm sectors have been studied. If environmental regulations influence inter-industry shifts, then regulations may also affect aggregate productivity.

There is significant reason to hypothesize that this may indeed be the case. The costs imposed by environmental regulations vary widely across industrial sectors. Depending on the portions of costs passed through to consumers and demand elasticities, there may be significant differences in the impact of environmental regulations upon the output of each sector. Hence the share of total output accounted for by sectors incurring high control costs may decrease, while the share of total output produced by sectors incurring low (or no) control costs may increase. Since productivity varies across sectors, the shifting of resources from one industry to another may change aggregate productivity.

Empirical Evidence

No empirical research testing this hypothesis was found.

General Equilibrium Hypotheses

Hypothesis #1 Productivity Decreases If Regulated Producers of Intermediate Goods Raise Prices to Cover Compliance Costs

If environmental regulations result in increased costs for regulated firms and industries, the price of their output may increase. Many firms and industries which incur high compliance costs produce largely intermediate goods such as iron and steel. Therefore, industries which buy inputs from regulated firms may also incur increased operating costs as a result of environmental regulations. This would tend to decrease productivity in non-regulated industries.

In general equilibrium models which capture these indirect effects, consequences may be similar to the direct regulatory impact upon regulated firms. Firms may substitute away from higher cost intermediate inputs immediately, or engage in research efforts to allow this in the future. Products may be reformulated and production processes may be redesigned to require less of the input. In short, uses of resources, and therefore productivity, may be altered as a result of these indirect effects.

Empirical Evidence

Input-output models have been used to trace the effects of regulation induced price increases in primary industries to industries consuming intermediate goods.[21] However, these studies do not then draw out the implications of intermediate product price increases on the productivity of consuming industries.

Some general equilibrium models incorporate input-output models in calculating inter-industry effects. This allows price increases in intermediate products to be traced throughout an economy's industries and the effects on productivity to be calculated. Summaries of the results of such studies are reported in Table 3.4.4.

Note, however, that these studies assume that regulated firms derive no off-setting benefits (i.e., marketable output) from their expenditures on pollution abatement and control. If regulated firms do in fact derive marketable output from expenditures to comply with environmental regulations, input-output models will overestimate increases in intermediate product prices and the resulting declines in productivity industries that consume intermediate goods.

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[21] For example, see Giarantanni (1974), Pasurka (1984) and Lieu (1986).

Table 3.4.4
Impact of Environmental Regulations Upon Productivity In General Equilibrium

Study	Analytic Framework	Economic Sector[1]	Productivity Measure	Inputs Diverted	Time Period	Percentage Impact on Annual Productivity Growth Rate
Data Resources Inc. (1981)	macroeconometric, input-output	aggregate	output per person employed	capital labour	1974-1979	-0.1 to -0.25
Evans (1973)	macroeconometric, input-output	aggregate	GNP per employee	labour	1972-1980	negative
Jorgenson and Wilcoxen (1990)	macroeconometric, input-output	35 sectors	labour productivity	capital labour	1947-1985	negative

Note:

1. All studies were conducted for the United States unless otherwise indicated.

3.5 Conclusions

Four general conclusions emerge from this review of productivity measurement and possible impacts on productivity of environmental protection regulations.

First, although many measurement issues arise, productivity is a well defined concept that has been applied in many empirical studies.

Second, there are numerous hypothesized transmission channels whereby environmental protection regulations may affect industrial productivity.

Third, relative to regulatory impacts on competitiveness, the practice of estimating regulatory impacts on productivity is well-developed. Estimates of regulatory impacts on productivity in the U.S., Canada's major trading partner, are available at the aggregate level and, to a lesser extent, for individual sectors.

Fourth, there are three broad approaches commonly used to test these hypotheses:

- estimate regulatory impacts under the assumption of full input diversion;
- estimate regulatory impacts using techniques that don't allocate the impact to an individual hypothesis; and
- estimate the regulatory impacts of one specific hypothesis (R&D, changes in economies of scale, etc.).

These four points led the consulting team, in conjunction with Ministry staff, to adopt relative productivity as the measure of competitiveness used in this study.

4.0 Empirical Framework and Data Sources

Summary

Understanding the study's methodology is critical to interpreting the empirical results. The methodology involves: (i) defining a measure of productivity; (ii) defining measures of regulatory burden; and (iii) developing and applying analytical frameworks to determine the relationships between (i) and (ii).

The multi-factor productivity of Ontario firms was measured using publicly available financial data and the following formula:

$$\text{Productivity} = \frac{\text{Output}}{c_k(\text{Capital Services}) + c_{lem}(\text{Labour, Energy and Material Inputs})}$$

where: output is defined as sales or revenue; capital services are defined as returns to capital (earnings); labour, energy and materials are the associated operating costs; and c_k and c_{lem} are the share of total costs accounted for by each set of inputs.

The historical impacts of the province's environmental regulations were estimated indirectly by estimating the relationship between our financial-based measure of productivity and firm-specific measures of "pollution intensity." Pollution intensity is measured in two ways: (i) total discharges of a pollutant; and (ii) total discharges of a pollutant per unit of sales. Data on industrial direct discharges to Ontario's waterways is available from the provincial government.

The relationship between the productivity of Ontario firms and their pollution intensity was evaluated for the period 1981-1989 using graphs, correlation statistics and single equation regression techniques. The following sectors and pollutants were included in the analysis:

- pulp and paper (suspended solids, biological oxygen demand);
- iron and steel (SS, ammonia, oil/grease, phenolics, cyanide, iron); and
- petroleum refining (SS, ammonia, phenolics, solvents).

Regulatory burden in the future is measured as the estimated costs to comply with proposed regulations under the Municipal-Industrial Strategy for Abatement (MISA), Ontario's program to control effluent discharges. Estimates of compliance costs for possible air emission regulations are also available.

To project future regulatory impacts, a growth accounting framework is used to estimate changes in productivity and productivity growth had the regulations been applied in the past. The growth accounting framework assumes that expenditures on environmental protection reduce on a *dollar-for-dollar basis* the resources firms have to spend on other activities.

Several preferred methodologies were found to be unfeasible due to data availability. Various checks were undertaken before concluding that these constraints do not appear to compromise the empirical results.

Chapters 2 and 3 addressed the first purpose of this study:

(i) to postulate mechanisms and hypotheses whereby environmental protection regulations affect industrial competitiveness and productivity.

In addition, these chapters provided direction for measuring productivity and ways in which regulatory impacts on productivity might be estimated.

This chapter details the methods adopted and data sources used to address the study's remaining two purposes:

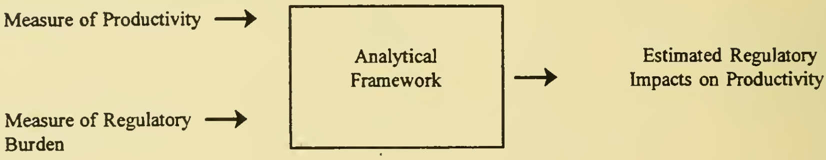
(ii) to estimate the *historical* impacts of Ontario environmental protection measures on Ontario industrial competitiveness and productivity; and

(iii) to estimate the likely *future* impacts of Ontario environmental protection measures on Ontario industrial competitiveness and productivity.

The information provided in this chapter is essential to interpreting the empirical results of the study. As illustrated in Exhibit 4.0.1, this information is of three types:

- the measures of competitiveness and productivity adopted;
- the measures of historical and future regulatory burden adopted; and
- the analytical frameworks ("set of rules") by which the quantitative relationship between the two variables is estimated.

Exhibit 4.0.1
Overview of the Empirical Approach


Measure of Productivity
Measure of Regulatory Burden
Analytical Framework
Estimated Regulatory Impacts on Productivity

The remainder of this chapter provides detailed information on:

- major constraints that limited the type of empirical work that could be carried out;
- definitions of variables;
- data sources;
- analytical frameworks adopted; and
- the strengths and weaknesses of the approach.

4.1 Constraints on the Study's Empirical Work

Three constraints had a major impact on the variables and analytical frameworks used in this study.

First, data availability played a key role in determining the overall approach to the empirical work. Little data exists with which to measure regulatory burden. Therefore, little choice was available to the project team regarding the variables that could be used.

The second constraint on the methodology is that the measures of regulatory burden and competitiveness must be comparable. For example, if measures of regulatory burden are available only for individual firms, then a measure of firm's competitiveness must be found. Only when measures refer to the same level of analysis (plant, firm, industry or national) can regulatory impacts be assessed.

Finally, the analytical framework adopted must be consistent with the data available. If data do not support the use of the analytical frameworks preferred for theoretical reasons, then alternative theoretical frameworks must be used.

All three of these constraints limited the work carried out in this study. Several preferred approaches which appeared feasible at the outset of the study were abandoned due to these constraints. In consultation with Ministry staff, a methodology that was feasible within these constraints was chosen.

Since the constraints necessitated compromises in methodology, many checks were undertaken to ensure that the methodology is sound. The results of these checks indicate that most theoretical drawbacks to the approach do *not* appear to compromise the study's findings.

However, despite these checks, findings must still be interpreted with caution. The definitions of key variables and the assumptions underlying the analytical frameworks should be thoroughly understood and kept in mind as the findings are reviewed. With this caveat, we proceed to present the study's methodology.

4.2 Measuring Historical Regulatory Burden in Ontario

The most commonly used measure of regulatory burden is compliance costs. Unfortunately, historical compliance costs incurred by Ontario industry are not generally available.[22]

In the absence of estimates of compliance costs, various measures of pollutant discharges can be used as indicators of regulatory burden. Incremental discharge reductions resulting from the regulation are the preferred indicator of regulatory burden. A measure of incremental discharge reductions would incorporate three factors:

- the level of discharges in the absence of regulations;
- the level of discharges allowed under the regulation; and
- the actual level of discharges.[23]

Unfortunately, all these data are not available. However, Ontario's water protection program does produce systematic data on direct pollutant discharges from industrial sources. Data on direct industrial discharges can be incorporated into numerous statistics, including indices of annual discharges and discharges per unit of output. Although they do not provide a direct measure of incremental discharge reductions attributable to environmental regulations, such measures do represent the *pollution intensity* of an industry. Environmental regulations, in turn, impact directly on pollution intensity.

Two major drawbacks to using this data exist. First, analogous data are not available for air emissions. Therefore, our historical analysis covers Ontario's water protection measures only. As shown in Exhibit 4.2.1, this may not pose a major problem for assessing regulatory impacts in the pulp and paper sector. For the Canadian pulp and paper industry, 62.2% of 1989 pollution abatement and control expenditures were devoted to water pollution. However, in Canada's primary metals and petroleum refining industries, this is not the case. Water protection efforts in these industries account for only 22.8% and 15.8% of total pollution abatement and control expenditures, respectively.

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[22] See Appendix D for a summary of the search for compliance cost estimates.

[23] For example, see the measure used by Gollop and Roberts (1983).

Exhibit 4.2.1
1989 Pollution Abatement and Control Expenditures in Canada by Pollutant Media

Industrial Sector	**Total Expenditures ($ millions)**	**Pollutant Media (% of Sector's Total PAC Expenditures)**			
		Air	Water	Contained Liquids	Solid Wastes
Primary Metals	489.8	54.7%	22.8%	2.3%	20.2%
Paper and Allied Products	368.8	20.2%	62.2%	3.2%	8.3%
Petroleum Refining	80.7	na	15.8%	na	6.1%

Source: Statistics Canada (1992).

Second, the available data focus on "traditional" pollutants. More recent and proposed regulations focus instead on toxic pollutants. Therefore, this historical analysis sheds little light on expected impacts of future regulations. A different framework is needed to project the impacts of proposed environmental protection regulations.

However, there are advantages to using water discharges to measure regulatory burden:

- they are reliable, as data are derived from verified monitoring;
- they are the data that drives Ontario's water regulations;
- they are available at a very disaggregated level (monthly observations, by plant for a wide variety of pollutants); and
- they indicate the pollution intensity of manufacturing operations through indices of annual discharges and discharges per unit of sales.

For these reasons, the historical analysis of this study focuses on the relationship between productivity and indices of pollution intensity. These pollution intensity indices are calculated using data on pollutant discharges direct to waterways and the following formula:

$$\text{Index}_t = (\text{Firm's Total Discharge in Year t}) / (\text{Firm's Total Discharge in 1985}).$$

4.3 Measuring Future Regulatory Burden in Ontario

Unlike historical regulatory burden, estimates of future compliance expenditures are readily available. The Ministry performs economic impact assessments as an integral component of the provincial water protection initiative, the Municipal-Industrial Strategy for Abatement (MISA). Assessments were also completed for possible changes to the province's air emission regulations. For the assessments, engineering cost estimates of the expected compliance expenditures required for each Ontario plant are produced. In the case of multi-plant firms, compliance costs are summed across plants to yield total compliance costs by firm.

Capital costs and operating and maintenance costs are available for a variety of regulatory scenarios. For possible changes to air emission regulations, the impacts of three scenarios are examined: the least stringent scenario for which cost estimates are available; the most stringent scenario; and a medium stringency scenario. Exact definitions vary across industries and are described in the references cited in Appendix D.

As with air regulatory scenarios, exact MISA scenarios vary across industry, depending on the technological abatement options available. Definitions of regulatory scenarios for the MISA program are described in references cited in Appendix D.

4.4 Measuring Ontario's Competitiveness and Productivity

As detailed in Chapters 2 and 3, there are compelling theoretical and practical reasons to adopt relative productivity or relative productivity growth as the measure of competitiveness used in this report. Furthermore, the productivity measure adopted must be comparable to the firm-level measures of regulatory burden that are available.

For these two reasons, the empirical component of this study uses firm-level productivity measures derived from corporate financial data. In particular, productivity is measured as:

$$\begin{aligned}\text{Productivity} &= \frac{\text{Output}}{\text{Divisia Index of Multiple Inputs}}\\ &= \frac{\text{Output}}{c_k(\text{Capital Services}) + c_{lem}(\text{Labour, Energy, Materials})}\end{aligned}$$

where c_k and c_{lem} are the shares of total cost accounted for by capital services and labour, energy and materials respectively. Note that output and inputs are all stated in real terms.

The data used to construct financial-based productivity measures come from two sources. Corporate annual reports provide statistics on output and inputs, while Statistics Canada provides price deflators for output and inputs. Exhibit 4.4.1 summarizes these data. Recall from Section 3 the supporting literature for this approach, as well as many of the general issues in implementing the approach.

Use of financial-based productivity measures is relatively limited. When possible, most analysts choose to construct productivity measures from industry-level data provided by government statistical agencies. Given

Exhibit 4.4.1

Definitions and Sources of Productivity Components

Component	Definition	Source
Output	Sales or revenues	Corporate Annual Reports
Output Deflator	Industry selling price for paper and allied products (SIC 27), primary metals (SIC 29) and refined petroleum and coal products (SIC 36)	Statistics Canada (various years) "Industry Price Indexes" Ottawa: Statistics Canada, Publication 62-011.
Capital Services	Net income	Corporate Annual Reports
Capital Services Deflator	Machinery and equipment price index for SIC 27, 29 and 36	Statistics Canada (various years) "Construction Price Statistics" Ottawa: Statistics Canada, Publication 62-007.
Labour, Energy and Materials (LEM)	Materials, labour and other expenses	Corporate Annual Reports
LEM Deflator	Implicit price deflator constructed from nominal and constant dollar input-output data for SIC 27, 29 and 36	Statistics Canada (various years) "The Input-Output Structure of the Canadian Economy" Ottawa: Statistics Canada, Publication 15-201. Statistics Canada (various years) "The Input-Output Structure of the Canadian Economy in Constant Prices" Ottawa: Statistics Canada, Publication 15-202.

that the approach is not common, it is worthwhile discussing in detail several issues regarding the financial-based productivity measures used here.

1. Accounting for Changes in Inventories

Inputs measured in a given period will include those inputs used to produce final and intermediate products that are not sold in that period. Therefore, the value of these production activities are not reflected in that period's sales. These products are instead captured as changes in inventories of final and intermediate products. This implies that productivity measures should add changes in inventories to sales in forming the numerator of productivity.

Corporate annual reports do not always provide data to adjust for changes in inventories. Although changes in inventories are often reported, they include changes in inventories of unprocessed materials as well as changes in inventories of final and intermediate goods. Sometimes no disaggregation is provided, nor is there a rule of thumb or general trend that would allow approximate disaggregation.

Taken together, these two considerations imply that:

- on theoretical grounds output should be adjusted for changes in inventories; but
- data on changes in inventories of final goods is not always available for making the adjustment.

Given these contradictions, it was decided to omit inventory adjustments from our productivity measure.

2. Measurement of Capital Services

Productivity studies generally define capital inputs as the flow of services derived from the capital stock. For the national and industry levels, the usual estimation procedure involves calculating the capital stock from investment data and assumptions regarding depreciation patterns, and applying a user cost of capital to this capital stock. This assumes that firms employ capital at the level where the marginal productivity of capital is equal to the user cost of capital.

The approach required with our financial data is somewhat different. Here we adopt the residual method of measuring capital inputs. Firms are assumed to employ inputs to the point where their marginal productivity is equal to their marginal costs. Under perfect competition, the portion of revenues not accounted for by operating costs is the return to capital and equal to the flow of capital services derived from the capital stock. Therefore, revenue net of operating costs is used as a measure of capital inputs.

A second issue relating to capital services is the choice between net capital stock or gross capital. In terms of our financial data, the issue becomes whether depreciation, as measured by accountants, should be subtracted from revenues along with operating costs to yield the return to the net capital stock.

Similar to studies cited in Section 3, our results do not vary significantly between productivity measures using the gross capital stock and those using the net capital stock. For example, Exhibit 4.4.2 presents the high correlation between productivity measures incorporating the gross and the net capital stock (statistics are presented for both inventory-adjusted and inventory-unadjusted productivity measures). Furthermore, estimates of productivity impacts are nearly identical for productivity measures using the net capital stock and the gross capital stock. In the apparent absence of any implications for the empirical results, the productivity measure is constructed using the gross capital stock.

3. Aggregation of Labour, Energy and Material Inputs

Labour, energy and material costs are aggregated into one component of the input index. Although it is often desirable to disaggregate inputs into more distinct categories, most sources of financial data do not provide breakdowns of operating costs.

4. Verification of Financial-Based Productivity Measures

In light of the uniqueness of our approach, care was taken to verify the accuracy of our productivity measure. Comparisons were made between our measure and measures used in two major studies examining Canadian industrial productivity. Exhibit 4.4.3 shows graphically the correspondence between productivity measures developed for this study and for studies undertaken by Statistics Canada and a research team based at the University of Toronto.

It should not be surprising that the measures do not always follow the same paths. First, Statistics Canada (1991a) and Denny et al. (1991b) calculate their measures for 2-digit SICs, whereas two of the financial-based productivity measures focus on three-digit industries (pulp and paper, and iron and steel). Second, the data used by Statistics Canada and Denny et al. include all Canadian companies within the sectors. The financial-based measures, on the other hand, incorporate only those companies located in Ontario and regulated under the MISA program. Finally, definitions of the data used to calculate the three productivity measures vary.

Despite these factors, the measures show similar trends during some time periods. From 1982 to 1985 financial-based measures track reasonably well the other measures for the pulp and paper and petroleum refining industries. These are the two sectors for which a large number of firms operating in the industry in Canada are included in the financial-based productivity measure. Financial-based productivity in the iron and steel sector does not correspond closely to the other productivity measures. This is not surprising since the financial-based measure used in this study incorporates only three iron and steel firms.

In those sectors for which our study captures a large number of firms, the similar trends displayed by financial-based productivity and other productivity measures justify greater confidence that financial-based productivity is a valid measure of production efficiency.

Exhibit 4.4.2
Correlation Between Financial-Based Measures of Productivity

Pulp and Paper Industry

	Gross K, I-Unadjusted	Gross K, I-Adjusted	Net K, I-Unadjusted	Net K, I-Adjusted
Gross K, I-Unadjusted	1.00	0.95	0.99	0.96
Gross K, I-Adjusted	--	1.00	0.95	0.99
Net K, I-Unadjusted	--	--	1.00	0.96
Net K, I-Adjusted	--	--	--	1.00

Iron and Steel Industry

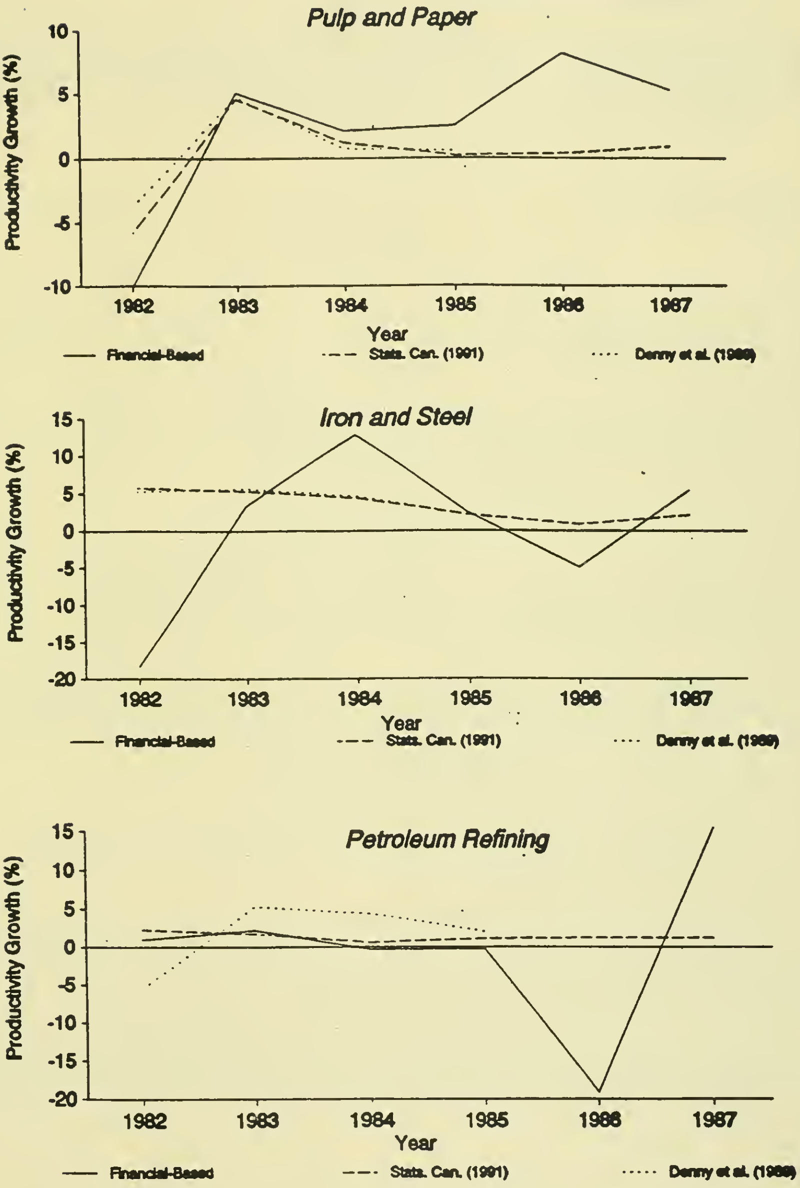
	Gross K, I-Unadjusted	Gross K, I-Adjusted	Net K, I-Unadjusted	Net K, I-Adjusted
Gross K, I-Unadjusted	1.00	0.97	0.99	0.97
Gross K, I-Adjusted	--	1.00	0.96	0.99
Net K, I-Unadjusted	--	--	1.00	0.97
Net K, I-Adjusted	--	--	--	1.00

Petroleum Refining Industry

	Gross K, I-Unadjusted	Gross K, I-Adjusted	Net K, I-Unadjusted	Net K, I-Adjusted
Gross K, I-Unadjusted	1.00	0.93	0.98	0.93
Gross K, I-Adjusted	--	1.00	0.91	0.99
Net K, I-Unadjusted	--	--	1.00	0.95
Net K, I-Adjusted	--	--	--	1.00

K = capital stock
I = inventories

Exhibit 4.4.3
A Comparison of Productivity Growth Measures



4.5 Analytical Frameworks Used to Estimate Impacts

The measures of regulatory burden and productivity used in this study are described above. Exhibit 4.5.1 reiterates these measures. We now discuss the analytical frameworks used to estimate the impact of environmental protection regulations on Ontario competitiveness and productivity. Recall that the analytical frameworks used must be suitable for the measures in Exhibit 4.5.1.

Exhibit 4.5.1
Summary of Measures Used in Empirical Work

Variable	Measure
Historical Regulatory Impacts	Index of Annual Discharges Index of Annual Discharges per unit of sales
Future Regulatory Impacts	Estimated Costs of Complying with MISA and Possible Air Emission Regulations
Competitiveness	Relative Productivity Relative Productivity Growth
Productivity	Financial-Based Productivity (output per unit of a multifactor Divisia index)

The first point to note in selecting suitable analytical frameworks is that the available measure of historical regulatory burden differs from the measure of future regulatory burden. This suggests that different analytical frameworks are likely necessary for estimating historical and future impacts. In fact, this is the case. We discuss below the frameworks used for each estimation.

Analytical Framework to Estimate Historical Impacts

The framework chosen to estimate the relationships between financial-based productivity and the measures of pollution intensity involves three techniques.

First, we present industry-specific graphs of productivity and pollutant data. These are the weighted average measures of productivity and pollution intensity across all firms in each sector. Pollutant discharges are represented by indices of annual discharges and discharges per unit of sales. These graphs allow "eye-balling" the aggregated data for any visible relationships.

Second, correlation coefficients estimate more formally the relationship between measures of pollution intensity and productivity. A positive correlation indicates that productivity and pollution intensity tend to move in the same direction. For example, if environmental regulations reduce pollution intensity and the correlation statistic is positive, productivity is expected to decline. A negative correlation indicates that productivity and pollution intensity move in opposite directions. If such a negative correlation is discovered, reductions in pollution intensity induced by regulations are expected to improve productivity.[24]

Finally, more formal analysis is conducted using regression analysis.[25] Regression analysis involves estimating relationships between dependent and independent variables. For example, regression analysis would provide estimates of a and b where:

$$Y = a + bX,$$

Y is the dependent variable and X is the independent variable. We describe below the dependent variables, independent variables and equations used in the study.

Dependent Variables

The relationships between environmental regulations and two dependent variables are assessed. The dependent variables are:

(i) $$\text{Productivity} = \frac{\text{Output}}{c_k(\text{Capital Services}) + c_{lem}(\text{Labour, Energy, Materials})}\text{; and}$$

(ii) $$\text{Productivity Growth} = \frac{\text{Productivity}_{\text{year } t} - \text{Productivity}_{\text{year } t-1}}{\text{Productivity}_{\text{year } t-1}}$$

Independent Variables: Regulatory Burden

Recall that historical regulatory burden is measured using data on direct discharges of various pollutants to waterways. Since environmental regulations affect pollution intensity, we estimate the relationship between the dependent variables and pollution intensity.

Different equations use different measures of pollution intensity. Specifically, we estimate the relationships between the independent variables and the four measures of pollution intensity:

(i) the index of annual discharges described above;
(ii) an index of discharges per unit of sales;
(iii) log(index of annual discharges); and
(iv) log(index of discharges per unit of sales).[26]

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[24] These correlations could occur due to one or more of the hypotheses described in Chapter 3.

[25] For an introduction to regression analysis and definitions of the technical terms used in subsequent sections of this report, see any introductory econometrics text book such as R. Pindyck and D. Rubinfeld (1981) *Econometric Models and Economic Forecasts* Toronto: McGraw-Hill Book Co.

[26] Regressions were also run using lagged measures of pollution intensity and growth rates in pollution intensity. However, these regressions did not produce any significant coefficient estimates and so are not discussed further.

By running regressions under the permutations allowed by the data, the possibility of many types of relationships between productivity and pollution intensity was explored. For example, log forms test for non-linear relationships and lagged values test for impacts that require up to several years to manifest themselves.

Dependent Variables: Control Variables

Control variables are dependent variables additional to the dependent variables of primary interest (those measuring regulatory burden).

Our inclusion of control variables is motivated by two factors. First, control variables offer another verification of the extent to which financial-based productivity reflects more traditional measures of productivity. Greater confidence in financial-based productivity measures is justified if significant determinants of non-financial-based measures are also significant determinants of financial-based measures. Second, we wish to lessen potential econometric problems with omitted variables. If significant explanatory variables are omitted and they are correlated with those variables included in the regressions, then coefficient estimates will be biased.

Both theoretical and empirical considerations guided the choice of control variables. It must be stressed that the goal of this study is not to explain the many sources of variations in Ontario industrial productivity. Rather our goal is to assess the role of environmental protection measures in determining productivity and competitiveness.

We include two major control variables in the regressions. These variables were selected because:

- formal theory or informal reasoning suggest they may influence financial-based productivity; and
- previous empirical studies, such as those cited in Section 3, generally find that they are significant determinants of productivity.

The first control variable is industry-specific capacity utilization rates (KUTIL). This measure of the intensity with which the capital stock is employed is expected to be positively correlated with productivity. As capital is employed more intensely, output per unit of capital should increase. Capacity utilization rates are provided by Statistics Canada.[27]

Second, exchange rates are also hypothesized to be major influences of financial-based productivity in the selected sectors. We assess the influences of two exchange rates obtained from Bank of Canada publications.[28] The first (EXCH1) is the Canadian dollar per U.S. dollar, while the second (EXCH2) is an index of the Canadian dollar relative to the currencies of 10 major industrialized countries.

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[27] Statistics Canada (various years) *Capacity Utilization Rates in Canadian Manufacturing Industries* Ottawa: Statistics Canada, Publication 31-003.

[28] Bank of Canada (various years) *Bank of Canada Review* Table 11.

It is ambiguous whether these exchange rates have a positive or negative influence on financial-based productivity. To illustrate, we take the example of an appreciation in the value of the Canadian dollar (a decrease in the exchange rate). Assuming that Canadian exporters are price takers in foreign markets, the Canadian dollar value of a given level of physical exports decreases. Since sales value declines, productivity tends to decrease.

However, Canadian manufacturers also import raw materials and capital goods. An appreciation will lower the cost of imported inputs, thus tending to increase productivity. The net effect of the appreciation on financial-based productivity is an empirical question.

In addition to controlling for capacity utilization and exchange rates, we also control for undefined firm-specific influences by including dummy variables for each firm, as well as firm-specific time trends. This reduces the chance that coefficient estimates for the pollutant variables may reflect excluded firm-specific variables that are correlated with pollutant variables.

Regression Equations

The regression equations have the following forms:[29]

$$\log(PROD) = \beta_0 + \beta_1\log(KUTIL) + \beta_2\log(EXCH1) + \beta_3\log(EXCH2) + \beta_4 POL1 + \beta_5 POL2 + \varepsilon$$

$$PRODGR = \beta_0 + \beta_1(KUTILGR) + \beta_2(\Delta EXCH1) + \beta_3(\Delta EXCH2) + \beta_4 POL1 + \beta_5 POL2 + \varepsilon$$

where PROD is the financial-based measure of productivity derived for each firm, PRODGR is the growth rate of productivity, KUTIL is the pertinent industry's capacity utilization rate, EXCH1 is the Canada-U.S. exchange rate, EXCH2 is the index of the Canadian dollar relative to the currencies of ten major industrial countries. For equations with productivity growth as the dependent variable, the control variables become the percentage change in capacity growth (KUTILGR) and the change in exchange rates (ΔEXCH1 and ΔEXCH2). POL1 and POL2 are measures of the pollution intensity of each firm's activities. Depending on the equation POL1 and POL2 could be any of the four measures of pollution intensity described above.

The exact type and number of pollutants included in the regressions vary across industries. For example, in the iron and steel industry, four pollutants are included: suspended solids, ammonia, phenolics, cyanide and iron.

Two very important results are taken from the estimated coefficients of pollution intensity variables. First, the significance of the coefficient (measured by the t-statistic) indicates whether or not the true coefficient is likely different from zero. If the t-statistic is below specified levels, then the estimated coefficients are not significantly different from zero. In these cases, we conclude that there is no relationship between productivity and pollution intensity evident from the regression.

Second, if the coefficient is significantly different from zero, the sign of the coefficient becomes important. A positive coefficient indicates that productivity and pollution intensity move in the same direction, while a negative coefficient suggests that they move in opposite directions. Interpretations of these relationships are the same as for positive and negative correlation statistics.

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[29] Firm-specific dummy variables and firm-specific time trends are also included.

Analytical Framework To Estimate Future Impacts

Perhaps the most common approach to projecting the financial impacts on industry of proposed regulations is "backcasting." Under this approach, estimates of compliance costs are used to shock historical financial data. The technique provides an estimate of how past financial performance would have been impacted if the regulations currently proposed had been implemented in the past.

The Ministry and many other environmental regulatory agencies have adopted this method of gauging the effects of proposed regulations. For example, the MISA economic assessments performed for BAT options entail collecting 10-year time series of data on firms' financial performance from corporate annual reports and other sources. Indicators of firms' profitability, solvency, liquidity and efficiency are "shocked" by netting out estimated compliance costs, thus yielding estimates of potential regulatory impacts.

The analysis performed in this report supplements the Ministry's MISA economic assessments. We calculate financial-based measures of firms' productivity and shock these historical statistics with estimated compliance costs.

Our analytical framework for calculating impacts is similar to that employed in the growth accounting studies of Denison, Norsworthy and others.[30] More specifically, it invokes the assumption that regulations divert inputs away from productive activities. This results in a decrease in output. Since firms employ inputs to the point where the marginal productivity of each input is equal to its marginal cost, the decrease in output is equal to the value of diverted inputs. In its simplest form, the growth accounting framework adjusts productivity for regulatory impacts according to the following formula:

$$\text{Adjusted Productivity} = \frac{\text{Output - Diverted Capital Services - Diverted Labour, Energy and Materials}}{c_k(\text{Capital Services}) + c_{lem}(\text{Labour, Energy, Materials})}$$

where variables are as defined before. All variables are in real monetary terms.

As explained in Chapter 3, the growth accounting approach estimates regulatory impacts under one assumption: dollar-for-dollar input diversion. If other channels whereby regulations could affect productivity are influential, then the actual effects may be different. For example, regulations may cause firms to replace old equipment with new equipment that is both more efficient and produces fewer contaminants. This will off-set to some extent adverse impacts on productivity. Similarly, firms' compliance strategies may transform former waste into marketable products. This would also have a mitigating effect. Such possibilities are not captured by the growth accounting framework.

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[30] See Section 3 for references.

Similar to the historical impact assessment, it must be noted that the available data allow for an assessment of the effects of Ontario regulations on firms' entire Canadian operations. Since corporate decisions are largely undertaken at the plant level, the analysis may be more relevant for firms with greater proportions of the activities in Ontario. Again, we test this hypothesis by calculating productivity impacts first for the entire set of firms, then for only those firms with their activities concentrated in Ontario.

4.6 Industrial Sectors Examined

Since compliance cost estimates are not yet available for some sectors, the study was limited to three sectors: pulp and paper, petroleum refining, and iron and steel. These three sectors generate large quantities of conventional and toxic contaminants and will be subject to any new pollution control regulations. Together, the sectors accounted for nearly 84% of 1989 pollution abatement and control capital expenditures in the Canadian manufacturing industries, and 75% of 1989 pollution abatement and control operating expenditures.[31] Furthermore, these three sectors spend higher proportions of their total capital expenditures on pollution abatement and control than any other sectors. Exhibit 4.6.1 presents supporting data on capital expenditures.

Exhibit 4.6.1
Pollution Abatement and Control (PAC) Capital Expenditures in Canada by Sector

Major Sectors	PAC Capital Costs (1989 $ millions)	Sectoral Distribution of PAC Capital Costs	PAC Capital Costs as a % of Total Sector Capital Costs
Total Manufacturing	702.1	76.7%	12.6%
Paper and Allied Products	292.8	32.0%	12.4%
Primary Metals	231.4	25.3%	20.4%
Refined Petroleum and Coal Products	63.5	7.0%	23.1%
Chemicals	56.1	6.1%	9.8%
Other Industries	58.3		
Utilities	85.0	9.3%	1.3%
Mining	69.6	7.6%	4.7%
Trade, Finance and Commercial	12.5	1.4%	4.0%
Canada	915.9	100.0%	6.2%

Source: Statistics Canada (1992).

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[31] These figures apply to the entire primary metals, paper and allied products, and refined petroleum and coal products industries. See Statistics Canada (1992).

Within these sectors, analysis was conducted using the firm-level data described above. The firms encompassed by this study are displayed in Exhibit 4.6.2. Firms were included on the basis of having data available to measure productivity and regulatory burden. Where possible, the data set covers nine years for each firm (1981-1989).

The end result is a cross-section data set that includes observations ranging across firms in each sector and across a time period of up to 8 years. Up to 63 observations are available for the pulp and paper sector, 40 for petroleum refining and 21 for iron and steel.

Exhibit 4.6.2
Firms Included in the Data Base

Pulp and Paper Sector	Petroleum Refining Sector	Iron and Steel Sector
Abitibi-Price Boise Cascade Domtar Great Lakes Forest Products Kimberly-Clark MacMillan Bloedel Malette Noranda Forest Products (owned by Fraser prior to 1986) Roman (owns Strathcona) Weston Resources (owns E.B. Eddy)	Imperial Oil Petro-Canada Shell Sunoco Texaco (prior to purchase by Imperial Oil)	Algoma Dofasco Stelco

4.7 Strengths and Weaknesses of the Approach

Estimation of regulatory impacts on productivity is very data intensive. This study was designed to examine what data are available and to estimate productivity and competitiveness to the extent possible. Given the available data, the approach is not ideal. Data restrictions necessitated some undesirable assumptions. Several of the most important issues are discussed below.

- Lack of historical data on air emissions or compliance costs prevent examination of the effects of past air protection initiatives. Therefore, estimates of historical impacts are possible for water protection measures only.
- Incremental reductions in effluent loadings directly attributable to regulations are not available. Instead, historical loadings provide measures of the "pollution intensity" of each sector or firm. While pollution intensity is not determined wholly by environmental protection regulations, regulations are influential.

- Productivity is measured using firm-level data for all operations in Canada. Loadings and compliance costs apply to Ontario operations only. Therefore, it is possible that the relationship between Ontario environmental protection regulations and firms' productivity is weak, but that very strong relationships may exist between Ontario regulations and the performance of individual Ontario plants. This implies that the results may be most significant for firms that have the greatest proportions of their activities located within Ontario.

  We test this hypothesis by estimating separately regulatory impacts on those firms with the highest proportion of their total production capacity in Ontario. When firms whose activities are concentrated outside Ontario are excluded from the database, results do not change significantly.

On the other hand, the approach has more to offer than simply being the most feasible approach. These include the following advantages.

- Financial performance is the over-riding concern among regulated firms. To the extent that this is reflected in corporate annual reports, this study examines regulatory impacts on firms' "bottom line."

- The data on loadings used for the historical assessment are the same data that has driven environmental regulations. Regulatory actions are taken as a direct result of this data base.

- The application of growth accounting techniques to corporate financial data offers a direct supplement to the economic assessments undertaken by the Ministry for its new environmental protection initiatives.

5.0 Regulatory Impacts on the Pulp and Paper Sector

Summary

This study provides no evidence to suggest that productivity in the pulp and paper industry, calculated using financial measures, has been adversely affected by environmental regulations (as proxied by changes in pollution intensity). Graphs show no clear relationship between productivity and the pollution intensity of either suspended solids or biological oxygen demand. Correlation statistics are generally small and negative, implying that as pollution intensity is reduced productivity is unaffected or may actually increase. Regression analysis supports the contention that pollution intensity is not a significant determinant of productivity or productivity growth. Therefore, environmental regulations which have reduced pollution intensity do not appear to have had significant impacts on productivity.

Several empirical estimates of regulatory impacts on the productivity of the U.S. pulp and paper industry are available. Since their results are contradictory, we cannot compare regulatory impacts on productivity. Further study is necessary to determine the impacts of environmental protection regulations on relative productivity. However, unless environmental regulations have resulted in significant *increases* to foreign productivity, domestic firms have likely not been disadvantaged.

Complying with Ontario's potential future air and water protection regulations is expected to reduce productivity in the pulp and paper industry by less than 1%. This implies that compliance costs associated with these regulations would reduce a productivity index with a value of 100.0 for a given year to 99.0. Compared to normal year-to-year fluctuations in productivity, this reduction is small. Effects on productivity growth are negligible.

No estimates of future regulatory impacts on the productivity of Canada's competitors are available. Therefore, the net impact of environmental regulations on relative productivity, the study's measure of competitiveness, remains unknown.

5.1 Overview of the Pulp and Paper Industry

The pulp and paper industry plays a key role in the Canadian economy.[32] In 1988, the sector's output, worth almost $27 billion, accounted for 6% of all manufacturing shipments. It was one of the largest industries in terms of value added, with almost $10 billion. Over 81,000 employees received nearly $3.3 billion in wages and salaries, making the industry the largest manufacturing employer in the country.

The Canadian pulp and paper sector also plays a disproportionately large role in international trade.[33] It produced almost 11% of total 1989 Canadian exports, the second largest exporter behind the auto sector. Nearly 67% of pulp and paper exports (51% of domestic production) was destined for U.S. markets. Canada accounted for 16% of world production of wood pulp (32% of world exports) and 30% of world production of newsprint (59% of world exports).

Ontario's share of this activity is substantial. Of the 144 pulp and paper mills in Canada, 36 are located in the province. Exhibit 5.1.1 presents various statistics summarizing Ontario's role in the national industry.

Exhibit 5.1.1
Ontario's Pulp and Paper Industry, 1988

Variable	Canadian Pulp and Paper Industry	Ontario's Pulp and Paper Industry	All Ontario Manufacturing Industries	Ontario's Share of National Industry	Industry's Share of All Ontario Manufacturing
Shipments	$20.6 billion	$4.7 billion	$192.2 billion	23%	2.4%
Value Added	$10.2 billion	$2.4 billion	$69.5 billion	24%	3.5%
Employees	81,058	20,157	993,795	25%	2.0%
Wages, Salaries	$3.3 billion	$0.8 billion	$30.1 billion	24%	2.7%

Sources: Statistics Canada (1991b).

Notes: 1. The pulp and paper industry is defined here as SIC 271.

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[32] The statistics cited are taken from Statistics Canada (1991b).

[33] Canadian Pulp and Paper Association (1990) summarizes Canadian trade in pulp and paper products.

5.2 Pulp and Paper, Productivity and Competitiveness

According to Statistics Canada (1991a), multi-factor productivity in the Canadian paper and allied products industry grew approximately 4% between 1961 and 1987.[34] The industry has not exhibited a general trend. Rather industry productivity has experienced periods of growth and decline.

Exhibit 5.2.1 graphs productivity measures calculated for this study, Statistics Canada (1991a) and Denny et al. (1991b). Note that the three measures move in tandem for the 1982-1985 period. Beyond 1985, our financial-based measure is more volatile than those derived in the other studies. The graph shows that productivity increased most rapidly as the economy recovered from the recession of the early 1980s. Since then productivity growth has been under one percent or, in the case of financial-based productivity, somewhat erratic.

As measured by relative productivity, the competitiveness of the Canadian paper and allied products industry has declined over time.[35] While Canadian productivity increased 3% between 1961 and 1986, productivity in the U.S. pulp and paper industry grew by almost 25% (Statistics Canada, 1991a). Exhibit 5.2.2 illustrates equally poor performance for recent years relative to the U.S. and Japan.

Exhibit 5.2.2
An International Comparison of Annual Productivity Growth Rates in the Paper and Allied Products Industry

	Annual Growth (%) 1954-1973	Annual Growth (%) 1973-1980	Annual Growth (%) 1980-1986	Annual Growth (%) 1954-1986
Canada	0.41	-0.18	-0.48	0.03
U.S.	0.68	-0.17	1.45	0.60
Japan	1.95	-0.68	0.41	1.26

Source: Denny et al. (1991b).

Note: Canadian statistics are for the periods 1961-1973, 1973-1980, 1980-1985 and 1961-1985 respectively.

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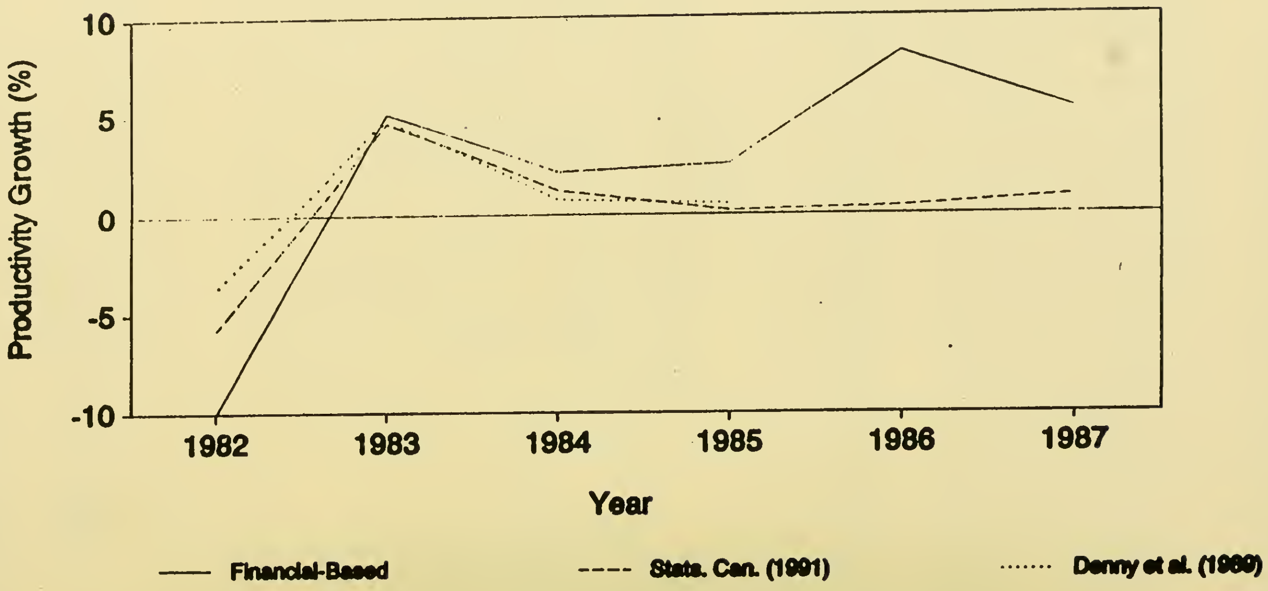
[34] A slightly lower value is calculated by Denny et al. (1991b).

[35] See Aktrin (1988) for further discussion of the international competitive position of the Canadian pulp and paper industry. It is important to realize that our discussion of competitiveness neglects significant differences between the sub-sectors of the industry.

Exhibit 5.2.1

A Comparison of Productivity Growth Measures in Canada's Pulp and Paper Industry



Further detail regarding historic productivity trends is provided by two studies (Denny, Fuss and May, 1981; Denny et al., 1991a). The first calculates productivity growth rates for Ontario, Quebec and British Columbia from 1961 to 1975. The second compares recent productivity growth in the same three provinces, as well as 10 U.S. states in which paper production is concentrated. Exhibit 5.2.3 summarizes these statistics. Caution must be exercised when comparing these productivity measures. Definitions of the underlying data vary across regions and time periods.

However, the exhibit does provide an indication of general trends in relative productivity. In particular, Ontario productivity growth has remained comparable to other areas, except for 1970 to 1975 where Ontario productivity declined at a somewhat higher rate than productivity in Quebec and British Columbia.

Exhibit 5.2.3
Productivity Growth in Ontario's Paper and Allied Products Industry Relative to Selected Provinces and U.S. States[1]

Jurisdiction	**Average Annual TFP Growth (%) 1961-1969**	**Average Annual TFP Growth (%) 1970-1975**	**Average Annual TFP Growth (%) 1975-1985**
Ontario	3.30	-0.97	-0.02
Quebec	3.21	-0.37	-0.07
British Columbia	3.31	-0.25	-0.37
Wisconsin	na	na	0.11
Pennsylvania	na	na	-0.07
California	na	na	-0.07
Georgia	na	na	-0.02
New York	na	na	-0.06
Illinois	na	na	-0.07
Alabama	na	na	0.08
Ohio	na	na	0.04
Washington	na	na	0.07
Michigan	na	na	0.05
Average All Regions	3.27	-0.53	-0.03

Sources: Denny, Fuss and May (1981) for 1961-1969 and 1970-1975; Denny et al. (1991a) for 1975-1985.

Notes: 1. Caution must be exercised when comparing productivity measures across periods and regions since variable and industry definitions may vary.

5.3 Historical Regulatory Impacts on Productivity and Competitiveness

As one of the first industries to be regulated by environmental regulators, the activities of the pulp and paper industry have long been recognized as posing potential risks to environmental quality and, in some cases, human health. To comply with environmental regulations, the industry has made relatively large expenditures on pollution abatement and control (PAC) activities.

Statistics Canada (1992) recently undertook a comprehensive survey of PAC expenditures. It found that the pulp and paper industry accounted for 42% of PAC capital expenditures and 16% of PAC operating expenditures made by Canadian manufacturers. Of these expenditures, 62% were made to control water pollution.[36] Exhibit 5.3.1 summarizes these expenditures.[37]

Exhibit 5.3.1
1989 Pollution Abatement and Control Expenditures by the Canadian Paper and Allied Products Industry

Expenditure Category	Total Expenditures ($ millions)	Pollutant Media (% of Total Expenditures)			
		Air	Water	Contained Liquids	Solid Wastes
PAC Operating	76.0	8.7%	57.7%	3.5%	30.1%
PAC Capital					
Construction	122.1				
Mach. & Equip.	170.7				
Total	292.8	23.2%	63.4%	3.1%	10.4%
Total PAC	368.8	20.2%	62.2%	3.2%	8.3%

Source: Statistics Canada (1992).

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[36] Other limited evidence suggests that about two-thirds of PAC expenditures during the 1970s were directed towards water discharges (Victor and Burrell, 1981).

[37] These costs are for "facilities and equipment which are *separately* identifiable and which have been installed *exclusively* for pollution and abatement control purposes" (Statistics Canada, 1992). Therefore, these figures focus on end-of-pipe investment, rather than the costs of process change that contribute to environmental and other objectives.

Though PAC expenditures made by the pulp and paper sector may be large relative to other industries, this does not reveal anything about the *impact* of these expenditures on the pulp and paper industry itself. A better indication of their significance is provided by Statistics Canada figures showing that the above costs represent 10.4% of the industry's total annual operating expenditures and 12.4% of the industry's total annual capital expenditures.

Recall from Chapter 4 that sufficient data on incremental compliance costs to estimate the relationship between productivity and environmental protection measures are unavailable. In their absence, pollutant discharges to Ontario waterways allow us to calculate several measures of the pollution intensity of individual pulp and paper firms. We examine the productivity impacts of two pollutants for which sufficient data are available. These are suspended solids (SS) and biological oxygen demand (BOD), the two pollutants with the longest history of regulation. Analytical techniques used are graphs, correlation statistics and regression analysis.

Graphical Assessment

Exhibit 5.3.2 compares annual productivity trends with indices of pollution intensity (recall definitions from Chapter 4). The first thing to note is that both annual discharges and discharges per unit of sales fluctuate more widely than productivity. Second, productivity appears to be independent of fluctuations in both annual discharges and discharges per unit of sales. For example, depending on the year, increases in productivity are accompanied by both increases and decreases in the pollution intensity indices.

A clear relationship between productivity growth and pollution intensity is also not visible in Exhibit 5.3.3.

Correlation Statistics

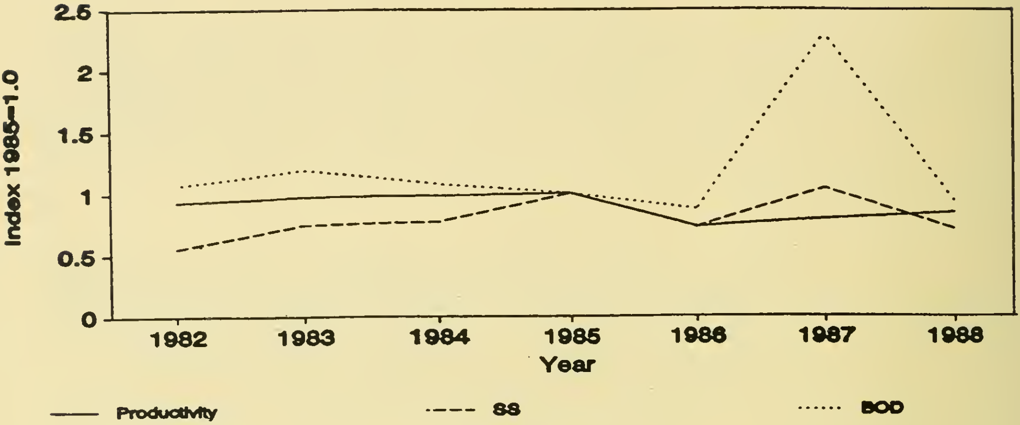
Relationships between productivity and pollution intensity are summarized numerically by the correlation statistics shown in Exhibit 5.3.4.

Exhibit 5.3.4
Correlation Between Productivity in the Pulp and Paper Industry and Pollutant Discharges

Pollution Intensity Index	Productivity	Productivity Growth
SS per year	0.04	0.09
SS per unit of sales	-0.37	-0.03
BOD per year	-0.04	-0.01
BOD per unit of sales	-0.19	-0.08

Exhibit 5.3.2

Trends in Productivity and Discharges in the Pulp and Paper Sector


Discharges Per Year

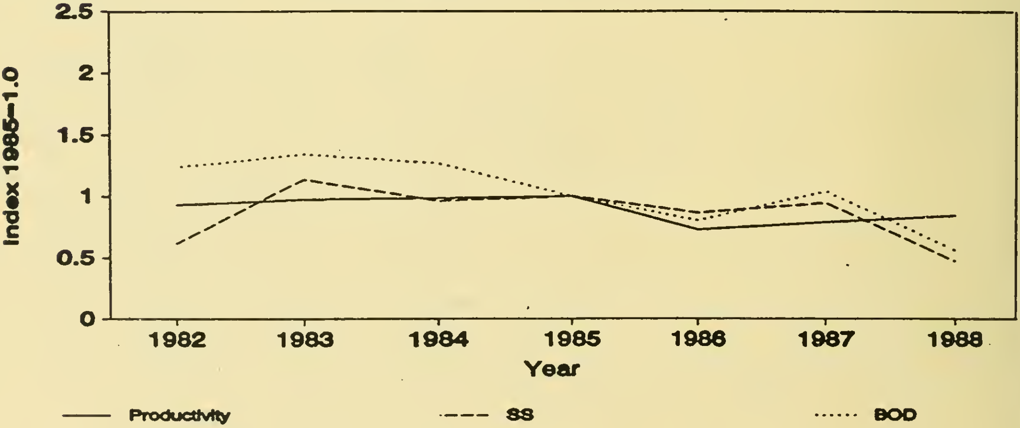
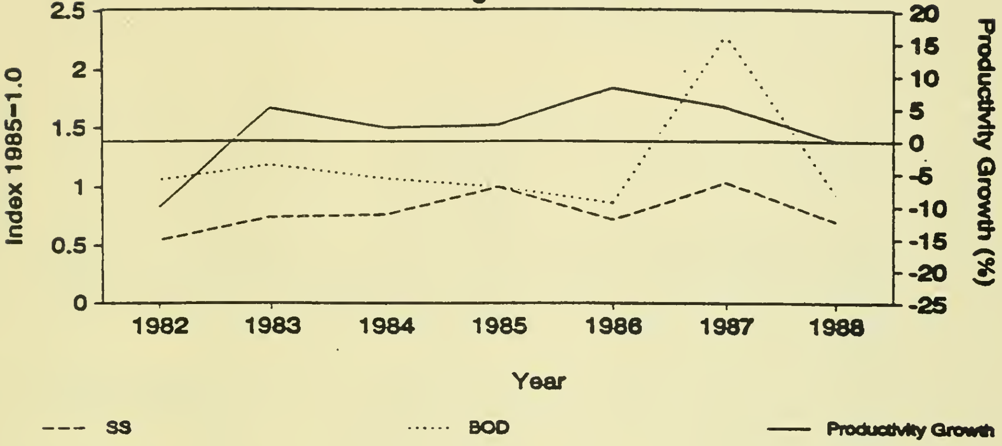
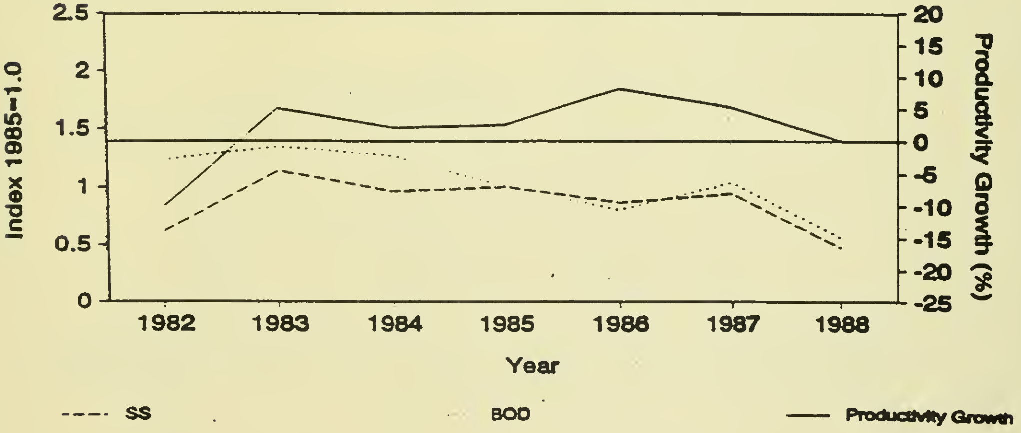

Discharges Per Unit of Sales

Exhibit 5.3.3

Trends in Productivity Growth and Discharges in the Pulp and Paper Sector



Discharges Per Year



Discharges Per Unit of Sales

The statistics reveal little correlation between indices of discharges per year and productivity or productivity growth. However, there does appear to be a negative correlation between discharges per unit of sales and productivity levels (-0.37 and -0.19 for SS and BOD respectively). This implies that, as discharges per unit of sales decrease, productivity increases. This could indicate that productivity enhancements result from measures to reduce the pollution intensity of production operations. On the other hand, a negative correlation could also occur if the inclusion of sales in both productivity and the measure of pollution intensity dominates the influence of other components of the variables. Therefore, the only clear conclusion is that a positive correlation does not exist.

Regression Results

As outlined in Chapter 4, included in the regressions are dummy variables for each firm and firm-specific time trends. We do not report these regression statistics as their meaning is ambiguous. However, a brief summary of the results is in order.

In the absence of dummy variables and time trends, an average of 10% of the variation in productivity is explained by capacity utilization, exchange rates and pollution intensity indices. When the dummies and time trends are included, up to 90% of the variation is explained. Individually, very few of the firm dummies and firm-specific time trends are significant. However, as a group, their significance is not rejected. Controlling for non-pollution, firm-specific influences increases the significance of capacity utilization and exchange rates. The effect on pollution intensity variables is mixed.

We also do not report regression results of equations with lagged discharges. Although lagged discharges are not at all significant, they do affect most other parameter estimates. In particular, nearly all parameter estimates become insignificant when lagged discharges are added.

Exhibit 5.3.5 presents regression results from five equations with productivity levels as the dependent variable. The equations vary according to how the pollutant discharge variables are defined. A number of general points are worth noting.

- The R-squared statistics indicate that the equations explain about 75% of the variation in productivity.
- The F-statistics indicate that, as a group, the independent variables are highly significant. The probability that all true coefficients are zero is less than 0.1%.
- Coefficients on capacity utilization (KUTIL) are of the expected sign and highly significant. These estimates verify, to some extent, the productivity measure.
- Exchange rates are not significant determinants of productivity.
- The explanatory power of the equations varies little with the specification of the pollution intensity variables.

Of most concern for this study is the fact that most coefficients of pollution intensity variables are not significantly different from zero. This implies that there is no support for the hypothesis that changes in pollution intensity affect productivity adversely. Therefore, environmental regulations that have influenced

Exhibit 5.3.5
Regulatory Impacts on Productivity in the Pulp and Paper Sector

Definition of Pollution Intensity Variables	Constant	KUTIL	EXCH1	EXCH2	SS	BOD	Adj R^2	F
D/DAY	-6.9077 (2.23)	1.5843 (2.40)	-0.7465 (1.02)	-0.8820 (1.07)	-0.0176 (1.54)	0.0010 (1.31)	0.76	8.86
Log(D/DAY)	-6.1311 (1.93)	1.4663 (2.15)	-1.3046 (1.83)	-1.2760 (1.60)	0.0485 (0.84)	-0.0388 (0.77)	0.75	8.37
D/SALES	-7.5123 (2.38)	1.7289 (2.56)	-1.2092 (1.77)	-1.4881 (1.87)	-0.0181 (1.50)	-0.0014 (0.51)	0.76	8.88
Log(D/SALES)	-7.4072 (2.56)	1.6499 (2.67)	-0.9264 (1.39)	-0.9961 (1.34)	-0.0139 (0.28)	-0.0664 (1.45)	0.79	10.14
Net Log(SS/SALES) Log(BOD/SALES)	-7.4072 (2.56)	1.6499 (2.67)	-0.9264 (1.39)	-0.9961 (1.34)	-0.0139 (0.28)	-0.0803 (2.56)	0.79	10.14

D denotes discharges.
Firm-specific dummy variables and time trends are not reported.
Net Log(SS/SALES) = Log(SS/SALES) - Log(BOD/SALES).
t-Statistics are given in parentheses.
Shading denotes significance at the 95% confidence level.

Observations: 63
Coefficients: 27

pollution intensity would not appear to have had negative impacts on productivity in the pulp and paper sector.

Note that it is possible that, by dividing both SS and BOD by sales, we are creating two independent variables that are highly correlated (see second and third regressions reported in Exhibit 5.3.5). If multicollinearity between these variables is present, coefficient estimates may be biased.

To check whether these coefficients were unbiased, a further regression was run (reported in the last row of Exhibit 5.3.5). Discharges were specified as BOD per unit of sales, as before. However, SS discharges were entered into the equation as SS discharges per unit of sales minus BOD discharges per unit of sales. This increased substantially the significance of the parameter estimate for the BOD variable, indicating that multicollinearity was indeed present in the former specification and that the final equation should be considered the better estimates.

This final regression yields a significant, negative coefficient for BOD discharges per unit of sales. This indicates that as pollution intensity increases, productivity decreases. The negative correlation offers some support that environmental protection initiatives could result in productivity enhancements such as production of marketable goods from pollution by-products, reduction in input costs and installation of more efficient and cleaner capital.

However, this is a very tenuous assertion. The negative relationship between pollution intensity and productivity is evident in only one specification. The results are not strong enough to be confident that productivity enhancements do result from environmental protection initiatives. Rather, we conclude that our approach does not find significant evidence of adverse impacts on productivity from reductions in pollution intensity.

Second, recall that our dependent variable measures productivity for firms' activities across Canada. It is possible that Ontario regulations adversely affect productivity within Ontario operations but that these effects are not strong enough to be reflected in total Canadian operations.

To test this possibility, we noted that pulp and paper firms vary widely according to the percentages of Canadian production accounted for by Ontario operations. Exhibit 5.3.6 summarizes this variation.

Exhibit 5.3.6
Pulp and Paper Production Capacity in Ontario

Company	% of Production Located in Ontario
Abitibi-Price	23.5%
Boise-Cascade	62.9%
Domtar	47.4%
Great Lakes Forest Products	41.2%
Kimberly Clark	100.0%
MacMillan Bloedel	6.9%
Malette	100.0%
Noranda Forest Products/Fraser	24.7%
Roman (owns Strathcona)	100.0%
Weston Resources (owns E.B. Eddy)	73.2%

Source: McCubbin, Bonsor and Owen (1990).

When we exclude those firms with less than 40% of production in Ontario (Abitibi-Price, Fraser, MacMillan Bloedel), parameter estimates remain nearly identical. The only noticeable difference in the regression results is a reduction in t-statistics caused by the fewer number of observations. Similar findings occur when a threshold of 60% Ontario sales is used. Thus, there appears to be little evidence that Ontario discharges affect more strongly the productivity of firms that operate primarily in Ontario than all Canadian firms in the complete data set.

The above results relate to the relationships between productivity levels and pollution intensity. We also examined productivity *growth* rates for evidence of a relationship with pollution intensity. These regressions are summarized in Exhibit 5.3.7.

Exhibit 5.3.7
Regulatory Impacts on Productivity Growth in the Pulp and Paper Sector

Dependent Variable: Productivity Growth Rate (gross capital stock, excludes inventory changes)

Definition of Pollution Intensity Variables	Constant	Growth Rate of KUTIL	Change in Can. $ per U.S. $	Change in Can. $ per G-10 Index	SS	BOD	Adj R^2	F
D/DAY	-0.4042 (0.42)	0.5810 (2.75)	-1.4348 (1.86)	-1.8971 (2.06)	0.0119 (1.71)	-0.0008 (1.61)	0.26	1.90
Log(D/DAY)	-0.3873 (0.40)	0.6556 (3.11)	-1.0367 (1.44)	-1.3225 (1.52)	0.0747 (1.56)	-0.0684 (1.60)	0.27	1.91
D/SALES	-0.3552 (0.37)	0.6097 (2.88)	-0.8785 (1.21)	-1.2385 (1.38)	0.0120 (1.03)	-0.0027 (1.19)	0.25	1.85
Log(D/SALES)	-0.5323 (0.56)	0.6856 (3.33)	-0.8714 (1.21)	-1.2075 (1.40)	0.0477 (1.08)	-0.0843 (2.06)	0.29	2.02
Net Log(SS/SALES) Log(BOD/SALES)	-0.5323 (0.56)	0.6856 (3.33)	-0.8714 (1.21)	-1.2075 (1.40)	0.0477 (1.08)	-0.0365 (1.11)	0.29	2.02

D denotes discharges.
Firm-specific dummy variables and time trends are not reported.
Net Log(SS/SALES) = Log(SS/SALES) - Log(BOD/SALES).
t-Statistics are given in parentheses.
Shading denotes significance at the 95% confidence level.

Observations: 63
Coefficients: 27

The equations do not explain productivity growth nearly as well as productivity itself. Adjusted R-squared statistics fall to less than 0.3, though the independent variables remain significant as a group. Once again, it is worth noting that the growth rate in capacity utilization is highly significant. Exchange rates are generally insignificant.

The estimated relationships between pollution intensity and productivity growth are consistently positive for SS and consistently negative for BOD. However, all but one parameter estimate is not significantly different from zero. Therefore, our results find no relationship between productivity growth and pollution intensity.

Impacts on Competitiveness

Our results do not support the hypothesis that previous environmental protection initiatives have had an adverse impact on productivity in the Canadian pulp and paper industry. This implies that environmental protection initiatives have likely not affected the industry's competitiveness, as defined by changes in relative productivity. In fact, if foreign environmental regulations have reduced productivity of foreign pulp and paper firms, environmental regulations have provided Canadian firms a competitive advantage over their rivals.

Two studies provide estimates of regulatory impacts on productivity in the U.S. pulp and paper industry between 1973 and 1980. These are summarized in Exhibit 5.3.8. The results convey a mixed message. It is unclear whether environmental regulations have increased or decreased productivity in the U.S. pulp and paper industry.

Exhibit 5.3.8
Environmental Regulatory Impacts on Productivity in the U.S Pulp and Paper Industry

Study	Period	Productivity Measure	Impact on Annual Productivity Growth Rate
Barbera and McConnell (1986)	1973-1980	Capital Productivity Labour Productivity	nil +0.5
Barbera and McConnell (1990)	1975-1980	Total Factor Productivity	-0.12

While no consensus exists regarding the regulatory impacts on productivity in the U.S. pulp and paper sector, it is interesting to note that some consensus does exist regarding regulatory impacts for the U.S. economy as a whole. Many studies indicate that U.S. environmental regulations have resulted in approximately a decrease of 0.1 in the productivity growth rate for the aggregate U.S. economy.[38] Given the industry's large share of total PAC expenditures, it is reasonable to speculate that the regulatory impact on productivity in the pulp and paper industry may be greater than average. If true, this would support the conclusion that differences in environmental regulations have provided Canadian pulp and paper firms with a competitive advantage relative to their U.S. competitors.

Since empirical evidence on relative productivity effects is limited, we briefly note several qualitative appraisals of the impact of environmental regulations on competitiveness in the international pulp and paper market. A simple comparison of regulations reveals that Canadian environmental regulations tend to lag behind those of our major foreign competitors, including the U.S. and Scandinavian countries (Bonsor, 1990). For example, pulp and paper effluent standards set by the U.S. Environmental Protection Agency (EPA) for U.S. pulp and paper firms are more stringent than Canadian standards and were largely met by 1984. At least four states have required that pulp and paper firms achieve more stringent levels of abatement than demanded by the EPA (James F. Hickling Management Consultants, 1990).

Regulatory impacts are not determined simply by regulations. Without enforcement, stringent regulations may not affect firms to any great degree. One study indicates that Ontario's regulations are enforced more stringently than other provinces and that Ontario per capita expenditures on monitoring and enforcement are three times greater than in the U.S. (James F. Hickling Management Consultants, 1990).

An additional factor in determining regulatory impacts is the degree to which regulations impose incremental reductions in discharges. One report indicates that, prior to significant regulations, U.S. pulp and paper firms were less pollution-intensive than Canadian firms. On average, effluent from U.S. mills in 1973 were of similar quality to effluent from Canadian mills in 1987 (McCubbin, Bonsor and Owen, 1990). Depending on the shape of marginal abatement cost curves, this could imply that expenditures to obtain the same level of abatement may be more costly for Canadian firms. Further study is necessary to verify this possibility.

General conclusions on past impacts of Ontario environmental regulations on the competitiveness of Canadian pulp and paper firms are difficult to draw. However, the data and methodology used in this report find little evidence to suggest that productivity and productivity growth in the Canadian pulp and paper industry have been affected by Ontario environmental regulations. Unless environmental regulations have resulted in significant increases to the productivity of foreign pulp and paper firms, the competitiveness of the domestic pulp and paper industry has likely not been hindered by Ontario's environmental regulations.

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[38] From large survey of empirical studies, Christainsen and Haveman (1981) conclude that 8-12% of t slowdown in productivity growth can be attributed to environmental regulations. The survey also sugges that from 1973 to 1978 U.S. aggregate productivity growth was 1.15 percentage points lower than previo periods.

5.4 Projected Regulatory Impacts on Productivity and Competitiveness

Ontario environmental regulations are undergoing great change. For example, the Municipal-Industrial Strategy for Abatement represents a significant departure from Ontario's previous environmental protection measures. Projecting their economic impacts is an integral component of these new initiatives.

Using the growth accounting framework described in Chapter 4, the following results were obtained. Exhibit 5.4.1 summarizes the reductions in productivity as a result of regulatory diversion of capital, operating and maintenance inputs.

Exhibit 5.4.1
Projected Regulatory Impacts on Productivity in the Pulp and Paper Sector

Regulatory Scenario	Percent Reduction in Average Productivity
MISA - Most Stringent	0.72%
MISA - Medium Stringency	0.42%
MISA - Least Stringent	0.37%
Most Stringent Air Regulation Scenario	0.04%
Medium Stringency Air Regulation Scenario	0.03%
Least Stringent Air Regulation Scenario	0.03%

Sources for compliance costs are described in Appendix D.

Overall, the results indicate that projected environmental regulations in Ontario will result in productivity decreases of less than 1%. Impacts on productivity growth are effectively zero and, therefore, are not reported.

Substantially different impacts will occur depending on the type of regulations. In particular, proposed air quality measures do not appear to have any noteworthy productivity effects. This appears reasonable given that air protection measures account for only a small proportion of PAC expenditures by the pulp and paper sector.

Note that, within the growth accounting framework, productivity impacts are additive. Promulgation of the most stringent MISA and air emission regulation scenarios would result in a total productivity decrease of 0.76%.

Projections for individual firms were also developed. They reveal that smaller firms operating exclusively in Ontario experience the greatest impact on productivity from Ontario water and air protection regulations. Productivity decreases over 1% are projected for three firms.

Recall that the growth accounting framework assumes that environmental protection expenditures do not offer any mitigating factors such as marketable output or reduced production costs. However, there is evidence to suggest that some offsetting benefits do accrue to regulated firms. For example, Boise Cascade, in their 1984 corporate annual report, acknowledged that "interesting and rewarding results have been achieved by engineers working to improve pollution control - some actually bringing us an economic return while succeeding in their environmental objectives." A review of corporate annual reports yielded two specific examples of offsetting benefits.

- Boise Cascade installed electrostatic precipitators that reduced ash emissions and enabled the mill to burn more wood waste, thus reducing energy costs (Boise Cascade Annual Report, 1990).
- Fraser Inc. (now part of Noranda Forest Products) experienced reduced maintenance shutdowns after installing six floating aerators for environmental protection purposes (Fraser Inc. Annual Report, 1986).

Statistics Canada (1992) surveyed firms regarding the magnitude of both 1989 PAC costs and offsetting benefits. The survey revealed that the PAC programs undertaken by the pulp and paper industry generated $0.9 million of revenue from the sale of recovered materials and reduced costs by a further $22.2 million. These revenues and cost savings represent almost 8% of the industry's operating expenses on PAC activities.

The magnitude of offsetting benefits remains unclear. However, this evidence does suggest that the assumption of full input diversion used in the growth accounting framework does not reflect reality. The growth accounting framework does not capture these offsetting benefits of environmental protection expenditure and, therefore, our estimates should be interpreted as *upper bound* estimates of regulatory impacts on productivity.

No projections of regulatory impacts on the productivity of foreign pulp and paper producers were found. Therefore, the net impact of environmental regulations on relative productivity, the measure of competitiveness used in this study, remains unknown.

6.0 Regulatory Impacts on the Iron and Steel Sector

Summary

Little evidence suggests that past fluctuations in pollution intensity affected past productivity performance in Ontario's iron and steel sector. The study explores the relationships between productivity and the intensity of six pollutants: suspended solids, ammonia, cyanide, iron, phenolic and oil and grease. Statistics measuring the correlation between productivity and pollution intensity are generally negative and/or close to zero. Regression analysis confirms that little relationship exists between productivity and pollution intensity. Similar conclusions hold for productivity growth and pollution intensity. These results imply that environmental regulations (which presumably affected pollution intensity) do not appear to be related to productivity.

Two studies estimate that environmental regulations have reduced the productivity growth of U.S. competitors during 1973 to 1980. Unfortunately, estimates of regulatory impacts for the period of this study, 1981 to 1988, are unavailable. More recent estimates are needed for conclusions regarding historical regulatory impacts on the competitiveness (relative productivity) of Ontario's iron and steel industry.

Projected estimates of the impact of Ontario's water protection program (MISA) on productivity in the iron and steel sector are roughly -1.5%. Impacts of similar magnitude result from all five levels of regulatory stringency being considered by the Ministry. Data were not available to project the impacts on productivity of possible air protection regulations.

No studies were found that projected regulatory impacts on the competitors of Ontario's iron and steel firms. Therefore, no conclusions can be made regarding future regulatory impacts on competitiveness, as measured by relative productivity.

6.1 Overview of the Iron and Steel Industry

In 1988, iron and steel shipments in Canada were worth just under $12 billion or roughly 4% of total manufacturing shipments.[39] The industry accounted for nearly $5 billion in value added, 3.7% of total value added by Canadian manufacturing industries. Its 62,000 employees received salaries and wages of $2.4 billion.

Exhibit 6.1.1 illustrates the prominence of the iron and steel industry in Ontario. About 70% of the national industry's activities are located in Ontario. Provincial iron and steel production is worth about $8.3 billion, or 4.3% of total provincial shipments of manufactured goods. The industry employs over 4% of all workers in Ontario manufacturing industries.

Exhibit 6.1.1
Ontario's Iron and Steel Industry, 1988[1]

Variable	Canadian Iron and Steel Industry	Ontario's Iron and Steel Industry	All Ontario Manufacturing Industries	Ontario's Share of National Industry	Industry's Share of All Ontario Manufacturing
Shipments	$11.9 billion	$8.3 billion	$192.2 billion	70%	4.3%
Value Added	$4.9 billion	$3.4 billion	$69.5 billion	69%	4.9%
Employees	62,362	40,821	993,795	65%	4.1%
Wages, Salaries	$2.4 billion	$1.7 billion	$30.1 billion	71%	5.6%

Source: Statistics Canada (1991b).

Note: 1. For reasons of confidentiality, Statistics Canada does not release data on Ontario's iron foundries (SIC 294). Therefore, Ontario data is for primary steel (SIC 291) and steel pipe and tube (SIC 292) only. Note that, at the national level, iron foundries account for about 9% of the iron and steel industry.

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[39] Summary statistics are taken from Statistics Canada (1991b).

6.2 Iron and Steel, Productivity and Competitiveness[40]

According to Statistics Canada (1991a), multi-factor productivity in the Canadian primary metals industry grew 15.4% between 1961 and 1986. Similar results were obtained by Denny et al. (1991b).

Exhibit 6.2.1 illustrates in greater detail trends in productivity growth of the national industry over recent years. Annual productivity growth in the primary metals industry, measured using aggregate Statistics Canada data, declined steadily from a high of about 5% in 1982 to less than 1% in 1986. Financial-based productivity measures incorporating three firms present in Ontario (Algoma, Dofasco and Stelco) is significantly more erratic than the other two measures for the national industry. Recovery from the recession during the early 1980s saw productivity growth rise from substantial negative rates to a peak of over 10% productivity growth in 1984. However, recovery was shortlived as productivity quickly entered another trough.

As measured by relative productivity in Exhibit 6.2.2, the overall competitiveness of the Canadian primary metals industry has steadily improved over U.S. competitors. Until 1980, productivity in the Japanese industry increased vis-a-vis both Canada and the U.S. However, in the first half of the 1980s, the Canadian industry achieved an average annual TFP growth rate over 0.25 percentage points greater than Japan and over 1.1 percentage points above the U.S.

Exhibit 6.2.2
An International Comparison of Annual Productivity Growth Rates in the Primary Metals Sector

	Annual Growth (%) 1954-1973	Annual Growth (%) 1973-1980	Annual Growth (%) 1980-1986	Annual Growth (%) 1954-1986
Canada	0.88	-0.59	1.11	0.56
US.	-0.23	-1.19	0.00	-0.54
Japan	1.39	0.83	0.85	1.14

Source: Denny et al. (1991b).

Note: Canadian statistics are for the periods 1961-1973, 1973-1980, 1980-1985 and 1961-1985 respectively.

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[40] For reasons of confidentiality, Statistics Canada does not release data with which to measure productivity in the iron and steel industry. Therefore, much of the discussion in this section focuses on productivity in the primary metals industry (SIC 29).

Exhibit 6.2.1

A Comparison of Productivity Growth Measures in Canada's Iron and Steel Industry

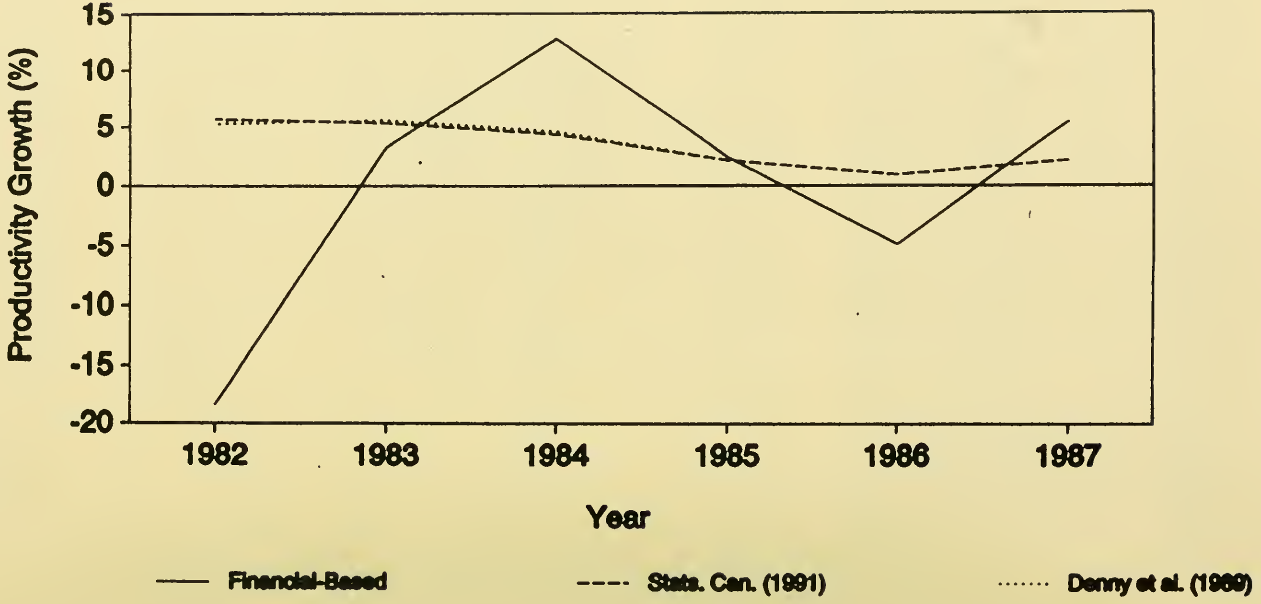


Exhibit 6.2.3 summarizes data on productivity growth in Ontario's primary metals industry. After a decade of average annual growth of 1.35%, productivity slowed to an average annual rate of 0.5% from 1970-1975. From 1975 to 1985, the industry's average productivity growth fell further to 0.41% per year.

Assessment of productivity and competitive trends in Ontario's iron and steel industry can be based on two studies (Denny, Fuss and May, 1981; Denny et al., 1991a). Exhibit 6.2.3 lists annual average growth rates in total factor productivity in the primary metals industries of Ontario, Quebec and British Columbia, as well as U.S. states where primary metal production is concentrated.

Exhibit 6.2.3 shows recent Ontario productivity growth well above U.S. competitors. While all the U.S. states listed experienced productivity declines of 1.4% or greater, Ontario productivity growth continued to grow at close to one-half percent per year. Productivity growth in Quebec and British Columbia is slightly higher than Ontario.

Exhibit 6.2.3
Productivity Growth in Ontario's Primary Metals Industry Relative to Selected Provinces and U.S. States[1]

	Average Annual TFP Growth (%) 1961-1969	Average Annual TFP Growth (%) 1970-1975	Average Annual TFP Growth (%) 1975-1985
Ontario	1.35	0.50	0.41
Quebec	1.11	0.56	0.63
British Columbia	1.72	1.49	0.62
Ohio	na	na	-1.80
Indiana	na	na	-1.66
Pennsylvania	na	na	-1.83
Illinois	na	na	-1.50
Michigan	na	na	-1.48
Texas	na	na	-1.41
New York	na	na	-1.63
California	na	na	-2.12
Average All Regions	1.39	0.85	-1.07

Sources: Denny, Fuss and May (1981) for 1961-1969 and 1970-1975; Denny et al. (1991a) for 1975-1985.

Notes: 1. Caution must be exercised when comparing productivity measures across periods and regions since variable and industry definitions may vary.

6.3 Historical Regulatory Impacts on Productivity and Competitiveness

Environmental regulations have required the iron and steel industry to undertake pollution abatement and control activities. In 1989, the Canadian primary metal manufacturers spent nearly $500 million on pollution abatement and control (PAC), including $231 million in capital expenditures and $258 million in operating costs. This represents about 30% of total Canadian PAC expenditures and 42% of PAC expenditures made by Canadian manufacturing industries. The iron and steel sector accounts for an unknown portion of PAC expenditures by the primary metals industry.

Exhibit 6.3.1 shows the distribution of these expenditures by pollutant media. Over half of PAC expenditures made by the primary metals industry are attributed to abating and controlling air emissions. Water protection programs account for 23% of PAC expenditures.

Exhibit 6.3.1
1989 Pollution Abatement and Control Expenditures by the Canadian Primary Metals Industry

Expenditure Category	Total Expenditures ($ millions)	Pollutant Media (% of Total Expenditures)			
		Air	Water	Contained Liquids	Solid Wastes
PAC Operating	258.4	41.9%	17.8%	3.7%	36.5%
PAC Capital					
Construction	137.2				
Mach. & Equip.	94.2				
Total	231.4	68.9%	28.3%	0.7%	2.1%
Total PAC	489.8	54.7%	22.8%	2.3%	20.2%

Source: Statistics Canada (1992).

Investment in PAC equipment and machinery account for 20.4% of capital expenditures made by the primary metals industry in 1989. The magnitude of this figure suggests that environmental protection regulations may have had an adverse impact on the industry's productivity. We test this hypothesis using the graphical, statistical and regression techniques described in Chapter 4 of the report.

Graphical Assessment

We begin by examining Exhibit 6.3.2. Exhibit 6.3.2 traces fluctuations in productivity and indices of six waterborne pollutants: suspended solids (SS), ammonia, oil and grease, phenolic (phenols), cyanide and iron. The relationship between productivity and discharges per day or discharges per unit of sales is unclear. While pollution indices rise and fall, productivity maintains a relatively stable level.

Exhibit 6.3.3 compares productivity growth with pollution intensity indices. Since the intensity of different pollutants move in different directions, no overall pattern emerges. More formal quantitative assessment is needed to discern relationships.

Correlation Statistics

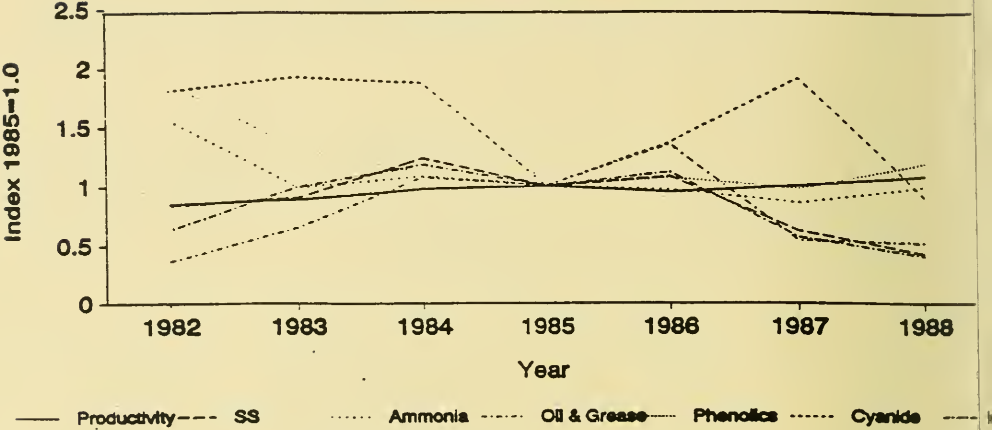
The correlation statistics presented in Exhibit 6.3.4 summarize the trends of Exhibits 6.3.2 and 6.3.3. Contrary to the graphs, these statistics reveal negative correlations between productivity and most of the pollution intensity indices. This implies that, as pollution intensity declines, productivity increases. This contradicts the hypothesis that reductions in pollution intensity resulting from environmental protection regulations adversely affect productivity or productivity growth.

Exhibit 6.3.4
Correlation Between Productivity and Pollution Discharges in the Iron and Steel Industry

Pollutant	Productivity vs Discharges per Day	Productivity vs Discharges per Unit of Sales	Productivity Growth vs Discharges per Day	Productivity Growth vs Discharges per Unit of Sales
Ammonia	-0.18	-0.21	-0.17	-0.19
Cyanide	-0.23	-0.41	-0.21	-0.33
Iron	-0.32	-0.46	-0.12	-0.20
Oil and Grease	0.01	-0.09	0.02	-0.05
Phenolic	-0.15	0.18	-0.14	0.03
Suspended Solids	0.06	-0.12	0.08	-0.02

Exhibit 6.3.2
Trends in Productivity and Discharges in the Iron and Steel Sector

Discharges Per Year



Discharges Per Unit of Sales

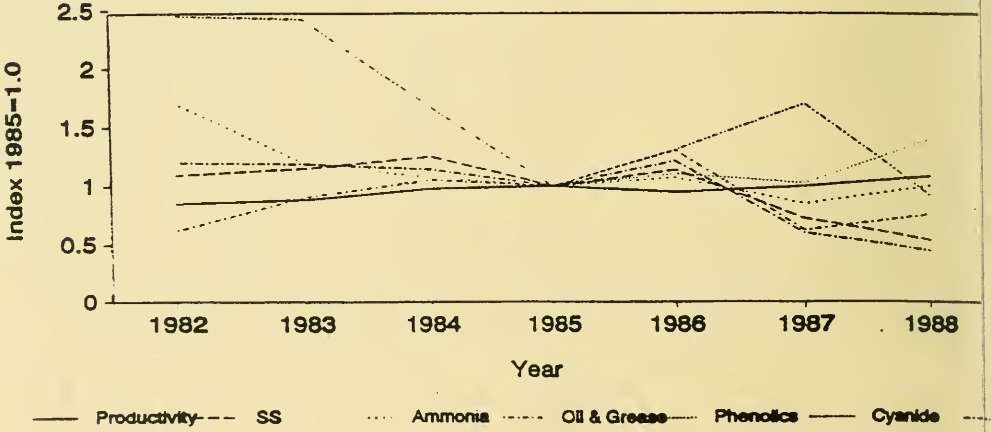
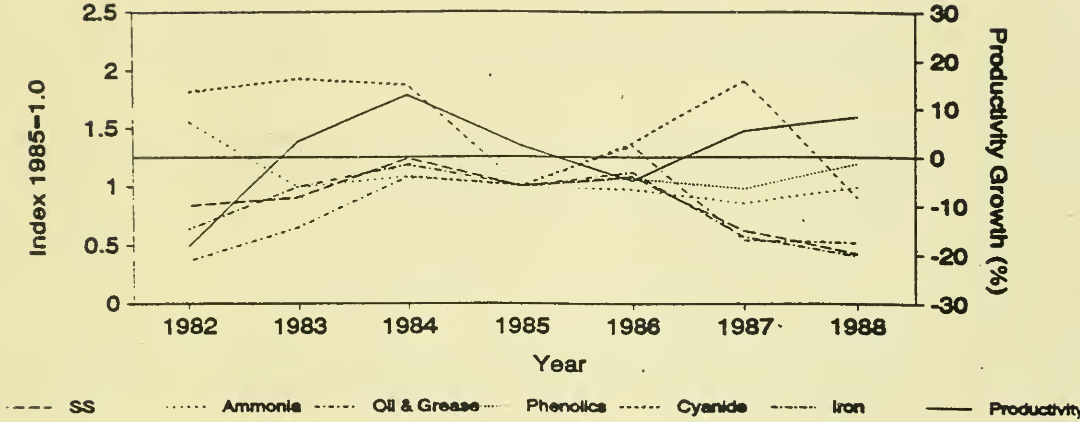
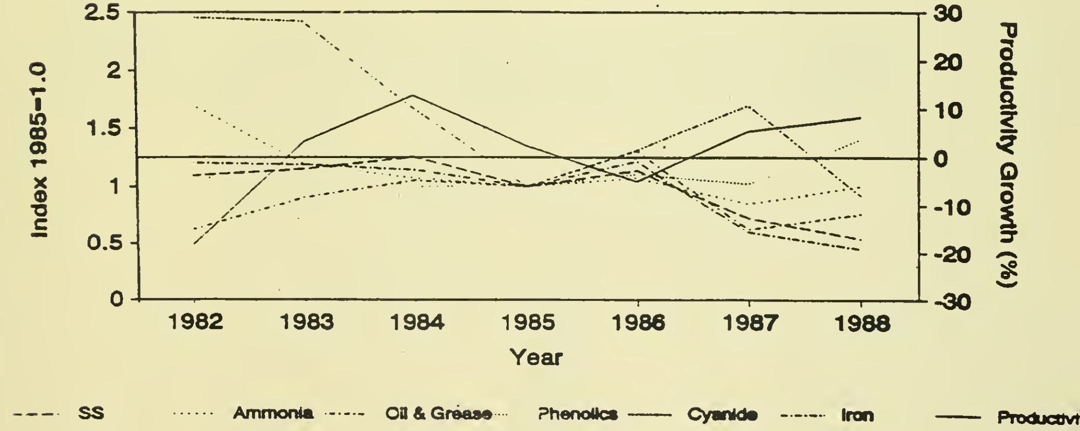


Exhibit 6.3.3
Trends in Productivity Growth and Discharges in the Iron and Steel Sector

Discharges Per Year



Discharges Per Unit of Sales



Regression Results

Although Exhibits 6.3.5 and 6.3.6 omit regression results for the firm-specific dummy variables and time trends, it is worth noting that their inclusion has a substantial effect. For example, when dummies and time trends are excluded from the regression equation, adjusted R-squareds decline to 0.10 to 0.15 from the 0.57 to 0.79 range presented in Exhibit 6.3.5, F-statistics drop well below the 95% confidence level and all estimated coefficients become insignificant.

We also do not report results of attempts to estimate equations that include lagged pollution intensity. There are insufficient observations available to support increasing the number of coefficients estimated for the iron and steel sector.

Exhibit 6.3.5 summarizes regression results obtained from equations with productivity as the dependent variable. The F-statistics indicate that there is a probability of 5% or less that all the true coefficients are zero. The adjusted R-squared statistics suggest that the independent variables explain between 57% and 79% of the variation in productivity in the iron and steel industry.

The estimated coefficients on capacity utilization are significant in three equations and of the expected sign. Controlling for changes in exchange rates does not yield significant coefficients.

The coefficients on the indices of pollution intensity are of most concern to this study. Significant, positive coefficients would suggest that regulation induced reductions in pollution intensity also reduce productivity. However, at the 95% confidence level, coefficients on pollution intensity variables in the iron and steel industry are not significantly different from zero. The natural log of phenolic discharges per unit of sales is significant and positive but only at the 90% confidence level.

Except for a reduction in the explanatory power of the independent variables as a whole, the results using productivity growth as the dependent variable resemble those for productivity levels (see Exhibit 6.3.6). Estimated coefficients on all pollution intensity indices remain insignificant at the 95% confidence level. However, once again, the log of phenolic discharges per unit of sales exhibits the most explanatory power.

For five of the six pollutants, there is no evidence to suggest that pollution intensity and productivity are related in the iron and steel sector. The regressions provide weak evidence that measures to reduce phenolic discharges from Ontario's iron and steel industry may have an adverse impact on the industry's productivity. However, given the very small number of observations used to estimate the equations, this is far from conclusive. Further light would be shed on this possibility by research into:

- the impact of regulations on phenolic discharges from the industry;
- the magnitude of expenditures made to reduce phenolic; and
- the types of abatement and control strategies adopted.

Exhibit 6.3.5
Regulatory Impacts on Productivity in the Iron and Steel Sector

Definition of Pollution Intensity Variables	Constant	KUTIL	EXCH1	EXCH2	SS	NH_3	Phenolics	Cyanide	Iron	Adj R^2	F
D/DAY	-4.2008 (0.66)	0.6772 (3.64)	0.4379 (0.30)	0.2588 (0.20)	0.00001 (0.87)	0.0001 (1.21)	0.0019 (1.41)	-0.0001 (0.17)	0.00002 (0.50)	0.79	7.15
Log(D/DAY)	0.2086 (0.03)	0.9529 (2.30)	-1.2055 (0.67)	-0.9310 (0.61)	0.00007 (0.00)	-0.0374 (0.32)	0.2304 (1.79)	-0.0992 (1.69)	0.0287 (0.14)	0.65	4.14
D/SALES	-3.9141 (0.45)	0.4542 (1.42)	0.8267 (0.42)	0.4264 (0.25)	0.00003 (0.34)	-0.0001 (0.32)	0.0103 (1.18)	-0.0022 (0.34)	-0.0002 (1.18)	0.57	3.26
Log(D/SALES)	-0.4269 (0.05)	1.0597 (2.52)	-0.8214 (0.44)	-0.6057 (0.38)	-0.1021 (0.42)	-0.0876 (0.70)	0.2749 (2.15)	-0.0983 (1.56)	0.0393 (0.18)	0.61	3.65

D denotes discharges.
Firm-specific dummy variables and time trends are not reported.
t-statistics are given in parentheses.
Shading denotes significance at the 95% confidence level.

Observations: 21
Coefficients: 13

Exhibit 6.3.6
Regulatory Impacts on Productivity Growth in the Iron and Steel Sector

Definition of Pollution Intensity Variables	Constant	Growth Rate of KUTIL	Change in $Can per $US	Change in $Can per G-10 Index	SS	NH_3	Phenolics	Cyanide	Iron	Adj R^2	F
D/DAY	0.2805 (1.36)	0.7918 (2.88)	2.2602 (1.29)	0.0068 (0.31)	-0.00001 (0.97)	-0.0001 (0.47)	0.0015 (0.75)	-0.0006 (0.45)	-0.0001 (0.85)	0.45	2.30
Log(D/DAY)	3.1546 (1.98)	0.9235 (4.24)	2.0379 (1.42)	0.0013 (0.07)	-0.2303 (1.36)	-0.0669 (0.77)	0.1913 (1.64)	-0.0724 (0.95)	-0.1293 (0.92)	0.53	2.83
D/SALES	0.2240 (1.95)	0.4844 (1.88)	1.5192 (1.31)	0.0126 (0.66)	-0.0001 (0.72)	-0.0006 (1.37)	0.0046 (0.60)	-0.0055 (0.94)	-0.0001 (0.56)	0.64	3.85
Log(D/SALES)	-1.3519 (1.61)	0.9143 (4.44)	1.5576 (1.22)	0.0015 (0.08)	-0.2948 (1.67)	-0.1002 (1.12)	0.2129 (1.90)	-0.0818 (1.16)	-0.0568 (0.42)	0.58	3.21

D denotes discharges.
Firm-specific dummy variables and time trends are not reported.
t-statistics are given in parentheses.
Shading denotes significance at the 95% confidence level.

Observations: 20
Coefficients: 13

Impacts on Competitiveness

The empirical analysis suggests that regulation induced reductions in pollution intensity have likely had little impact on productivity in the iron and steel sector. To assess impacts on the domestic industry's competitiveness, we examine the *relative* impact of environmental regulations.

Two U.S. studies have estimated productivity changes in the iron and steel (or primary metals) industry. These studies, summarized in Exhibit 6.3.7, suggest that, during the 1970s, environmental regulations reduced labour, capital and total factor productivity growth in the U.S. More recent estimates are unavailable.

Exhibit 6.3.7
Environmental Regulatory Impacts on Productivity in the U.S Iron and Steel Industry

Study	Period	Productivity Measure	Impact on Annual Productivity Growth Rate
Barbera and McConnell (1986)	1973-1980 (primary metals)	Capital Productivity Labour Productivity	-0.77 -0.55
Barbera and McConnell (1990)	1975-1980	Total Factor Productivity	-0.15

If productivity in the U.S. iron and steel industry continued to be adversely affected by environmental regulations during the 1980s, and if our findings of no regulatory impacts on productivity in the domestic industry is correct, then environmental regulations have resulted in a de facto increase in the competitive position of the domestic industry vis-a-vis its U.S. competitors. More recent estimates of regulatory impacts on U.S. productivity are needed for further conclusions.

6.4 Projected Regulatory Impacts on Productivity and Competitiveness

Financial-based productivity, estimated compliance costs and the growth accounting framework are used to project the impacts on productivity of Ontario's water pollution regulations. Unfortunately, the estimated costs of complying with possible air regulation scenarios are not available on a firm-specific basis. As explained above, roughly 55% of the iron and steel industry's PAC expenditures were devoted to air protection programs, while water protection programs accounted for 23%. If this relative magnitude is indicative of the compliance costs the industry will incur in the future, our projections reflect only about one-quarter of the potential regulatory impacts on the industry's productivity.

The Province's water protection program, MISA, is establishing effluent regulations based on Best Available Technology (BAT). Currently, the Ministry is considering four possible BAT options for the iron and steel industry. Exhibit 6.4.1 presents the projected impacts on productivity of each of these BAT scenarios. The impact of related monitoring costs is also included in the projections.

Exhibit 6.4.1
Projected Regulatory Impacts on Productivity in the Iron and Steel Sector

MISA BAT Option	Percent Reduction in Average Productivity
Best in Ontario	1.53%
Best in USA	1.49%
Best in World	1.63%
Non Lethal	1.63%

Sources: Compliance costs were provided by the Ontario Ministry of the Environment.

The BAT options proposed for the iron and steel industry are estimated to reduce productivity levels by approximately 1.5%. It is interesting to note that impacts do not vary considerably between the different options. No impact on productivity growth is evident.

These projected impacts on productivity assume that compliance costs do not contribute to output or result in lower production costs. However, as in the pulp and paper industry, there is some evidence to suggest that iron and steel firms experience off-setting benefits from some pollution abatement and control expenditures. The following examples illustrate the potential.

- Statistics Canada (1992) surveyed industry to obtain information regarding PAC expenditures and off-setting benefits. In particular, the survey revealed that, in 1989, PAC expenditures made by the primary metals industry generated $43.4 million from two sources: revenues from the sale of PAC recovered materials ($23 million) and cost savings from using PAC recovered materials ($20.4 million).

- In 1989, Ivaco reported that "feasibility studies are underway to examine the potential for the use of new technology to treat steelmaking flue dust and render it non-hazardous. Early indications suggest that recovery of valuable materials, principally prime wester zinc, will make this environmentally beneficial operation completely cost effective" (*1989 Annual Report*).

- In 1988, Stelco announced investment in electric arc furnaces and ladle metallurgy stations that "incorporate environmental control and quality improvements and increase plant capacity by 80,000 tons annually" (*1988 Annual Report*).

- According to Dofasco's 1990 Annual Report, $55 million were generated from the collection, refining or reprocessing, and sale of by-products. It is likely that collection of some of these by-products contributed to achieving compliance with environmental regulations.

Of course, the extent to which these mitigating factors may off-set PAC expenditures is uncertain. The PAC revenues and cost savings estimated by Statistics Canada (1992) represent 9% of total PAC expenditures by the primary metals industry. However, the survey was limited in scope and this figure should not be viewed as definitive.

Projections of regulatory impacts on the productivity of foreign competitors in the iron and steel industry were not found. Therefore, data do not exist to assess future impacts on competitiveness (relative productivity) of environmental regulations.

7.0 Regulatory Impacts on the Petroleum Refining Sector

Summary

Our empirical analysis does not reveal any unambiguous relationship between environmental regulations and productivity in Ontario's petroleum refining sector. Four water pollutants were examined: suspended solids, ammonia, phenolic and solvents. Correlation statistics suggest a positive relationship between productivity and pollution intensity. However, the regression analysis finds no significant relationship between productivity and pollution intensity. Therefore, there is not strong enough evidence to conclude that environmental regulations which reduced water pollution intensity affect productivity.

It is important to realize that the historical analysis covers only Ontario's past water protection programs and, therefore, excludes the possible impacts of expenditures to reduce air and solid waste emissions. In 1989, approximately 16% of total pollution abatement and control expenditures by petroleum refiners was devoted to water protection. Therefore, our analysis is relevant to a relatively small portion of the industry's environmental protection activities. A more complete investigation of regulatory impacts on productivity should take into account abatement and control of other forms of pollution.

Projections were made of the impacts on productivity of Ontario's water and air protection measures. Estimated productivity declines are very small. If the most stringent of suggested water and air regulations are adopted, compliance costs would reduce productivity by less than 0.2%.

No estimates of future regulatory impacts on the productivity of petroleum refiners in other jurisdictions were found. Therefore, future impacts on competitiveness, measured by relative productivity, are unknown.

7.1 Overview of the Petroleum Refining Sector

The petroleum refining industry is a major Canadian industry contributing 4.4% of all manufacturing shipments and 1.7% of manufacturing value added.[41] The industry accounts for a smaller portion (0.8%) of employment in all Canadian manufacturing industries.

Seven petroleum refineries are located in Ontario. As shown in Exhibit 7.1.1, these establishments generate shipments worth $5.7 billion (3% of all shipments from the province's manufacturing industries). This production represents about 1.4% of Ontario's manufacturing value added. Over 7,500 workers receive wages and salaries worth just under $400 million.

Exhibit 7.1.1
Ontario's Petroleum Refining Industry, 1988[1]

Variable	Canadian Petroleum Refining Industry	Ontario's Petroleum Refining Industry	All Ontario Manufacturing Industries	Ontario's Share of National Industry	Industry's Share of All Ontario Manufacturing
Shipments	$15.1 billion	$5.7 billion	$192.2 billion	38%	3.0%
Value Added	$2.3 billion	$1.0 billion	$69.5 billion	43%	1.4%
Employees	15,610	7,635	993,795	49%	0.8%
Wages, Salaries	$726 million	$377 million	$30.1 billion	52%	1.3%

Sources: Statistics Canada (1991b).

Notes: 1. The "petroleum refining industry" is defined here as SIC 36, Refined Petroleum and Coal Products. Coal products account less than 2% of shipments in SIC 36.

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[41] Statistics Canada (1991b) provides the data presented in the overview.

7.2 Petroleum Refining, Productivity and Competitiveness

As summarized in Exhibit 7.2.1, Statistics Canada (1991a) estimates that multi-factor productivity in the Canadian refined petroleum and coal products industry grew approximately 17.7% between 1961 and 1986. Productivity growth averaged about 1 percent per year between 1961 and 1973. With the subsequent increases in real oil prices, productivity growth was negative during the remainder of the 1970s. Productivity growth recovered during the first half of the 1980s with an average growth rate of 1.1%.

Denny et al. (1991b), on the other hand, estimate somewhat different trends. Although productivity growth in the 1973-1980 period is substantially lower than in the 1961-1973 period, the average annual productivity growth rate does not become negative. Furthermore, productivity growth estimated by Denny et al. does not recover in the 1980 to 1985 period.

Exhibit 7.2.1
Productivity Trends in the Canadian Petroleum Refining Industry
(average annual productivity growth rate, %)

Time Period	Statistics Canada (1991a)	Denny et al. (1991b)
1961-1973	1.06	0.39
1973-1980	-0.09	0.05
1980-1985	1.13	0.09
1961-1985	0.74	0.18

Exhibit 7.2.2 presents in greater detail productivity trends for the time period of most interest to this study. From 1982 to 1985, financial-based productivity growth follows closely the results of Denny et al. (1991b), while Statistics Canada (1991a) measures more erratic patterns. However, from 1985 to 1987 financial-based productivity registers a substantial one-year dip and recovery. This is accounted for by large fluctuations in the price of crude oil, the single most important input to the industry.

Statistics Canada (1991a) and Denny et al. (1991b) find similar trends in the competitiveness of the Canadian petroleum refining industry. Statistics Canada (1991a) estimates that while U.S. petroleum refining productivity grew 8.6% from 1961 to 1986, Canadian productivity grew nearly 18%. Estimates by Denny et al. (1991b), presented in Exhibit 7.2.3, indicate an increase in Canadian productivity relative to U.S. and Japanese industries from 1961 to 1986.

Exhibit 7.2.2

A Comparison of Productivity Growth Measures in Canada's Petroleum Industry

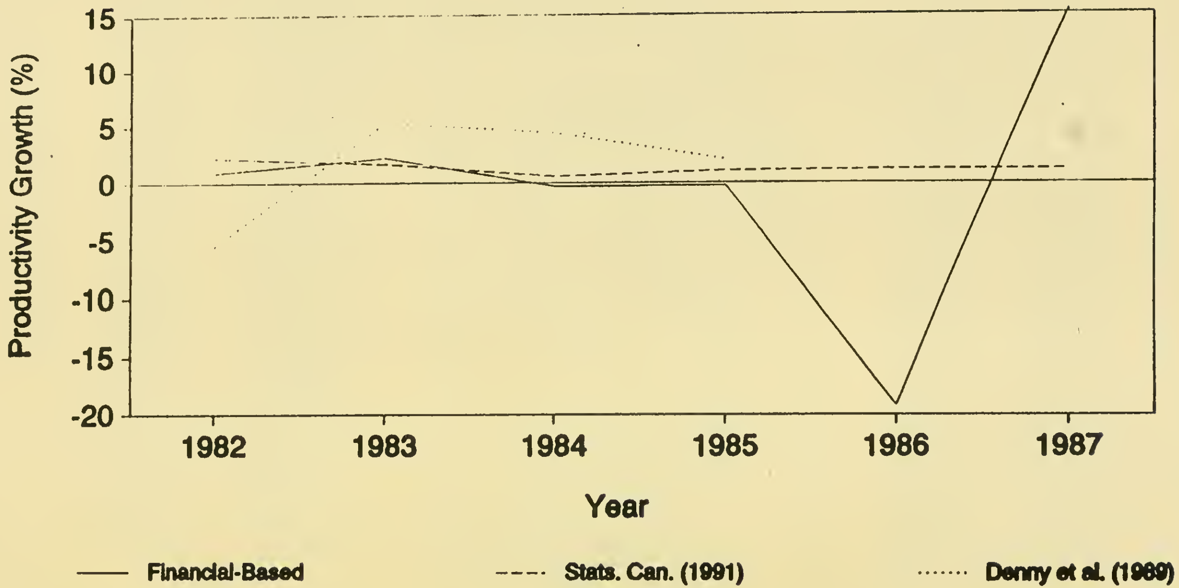


Exhibit 7.2.3
An International Comparison of Annual Productivity Growth Rates in the Petroleum Refining Sector

	1954-1973	1973-1980	1980-1986	1954-1986
Canada	0.39	0.05	0.09	0.18
U.S.	0.81	-0.16	-0.25	0.34
Japan	2.04	-0.25	-6.58	1.42

Source: Denny et al. (1991b).

Note: Canadian statistics are for the periods 1961-1973, 1973-1980, 1980-1985 and 1961-1985 respectively.

Other work by Denny et al. (1991a) estimates petroleum refining productivity growth rates in the Ontario, Quebec, British Columbia and 5 U.S. states where petroleum refining is concentrated. These findings are summarized in Exhibit 7.2.4. From 1975 to 1985, productivity declined in all jurisdictions. However, the decline in Ontario was less than that experienced in other provinces and similar in magnitude to declines in the U.S. Therefore, we conclude that, in that time period, the competitiveness of the industry in Ontario did not decline relative to these jurisdictions.

Exhibit 7.2.4
Productivity Growth in Ontario's Petroleum Refining Industry Relative to Selected Provinces and U.S. States[1]

	Average Annual TFP Growth (%) 1961-1969	Average Annual TFP Growth (%) 1970-1975	Average Annual TFP Growth (%) 1975-1985
Ontario	1.46	-0.13	-0.31
Quebec	1.49	-0.03	-0.92
British Columbia	na	na	-1.41
Texas	na	na	-0.26
Louisiana	na	na	-0.17
California	na	na	-0.34
Illinois	na	na	-0.32
Ohio	na	na	-0.29
Average All Regions	1.48	-0.08	-0.50

Sources: Denny, Fuss and May (1981) for 1961-1969 and 1970-1975; Denny et al. (1991a) for 1975-1985.

Notes: 1. Caution must be exercised when comparing productivity measures across periods and regions since variable and industry definitions may vary.

7.3 Historical Regulatory Impacts on Productivity and Competitiveness

Petroleum refineries discharge a number of pollutants covered by environmental protection regulations. To comply with regulatory requirements, the petroleum refining industry has undertaken pollution abatement and control programs costing just over $80 million in 1989 (see Exhibit 7.3.1).

Exhibit 7.3.1
1989 Pollution Abatement and Control Expenditures by the Canadian Petroleum Refining Industry

Expenditure Category	Total Expenditures ($ millions)	Pollutant Media (% of Total Expenditures)			
		Air	Water	Contained Liquids	Solid Wastes
PAC Operating	17.2	na	41.8%	na	13.7%
PAC Capital Construction Mach. & Equip. Total	 na na 63.5	na	8.8%	na	4.0%
Total PAC	80.7	na	15.8%	na	6.1%

Source: Statistics Canada (1992).

These 1989 figures suggest that pollution abatement and control programs implemented by the petroleum refinery are capital intensive. Over three-quarters of PAC expenditures are devoted to capital investments. Indeed, roughly 23% of 1989 capital expenditures made by the petroleum industry were devoted to PAC programs.

Although the industry's water protection programs account for over 40% of the industry's PAC operating expenditures, nearly 80% of capital PAC expenditures relate to air and contained liquids. Unfortunately, data on the intensity of air emissions were not available to measure the historical impact of air protection measures on productivity. It is important to keep in mind that the findings presented below pertain only to water protection programs that accounted for just 16% of the industry's PAC expenditures in 1989.

Graphical Assessment

The analytical approaches applied to the other two sectors were also applied to the petroleum refining industry. Exhibit 7.3.2 begins by comparing graphically the productivity index for the petroleum refining industry with indices of pollution intensity for suspended solids (SS), solvent extract, phenolic and ammonia-nitrogen. Exhibit 7.3.3 substitutes productivity growth for productivity.

Several points are noteworthy.

- The intensity of all four pollutants, measured in both discharges per day and discharges per unit of sales, tend to move in tandem.
- Relative to the productivity index, pollution intensity indices experience greater fluctuations.
- Neither the productivity index nor productivity growth appear to be highly correlated with the pollution indices.

Correlation Statistics

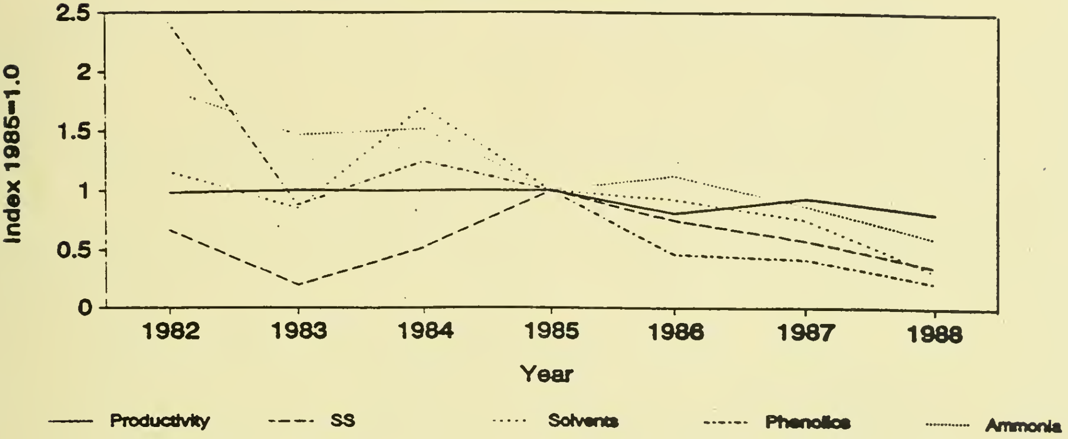
The correlation statistics in Exhibit 7.3.4 assess more formally the potential relationships between productivity and pollution intensity. The correlation statistics estimate a consistently positive relationship between productivity and pollution intensity. As pollution intensity of petroleum refining operations decrease, productivity and productivity growth also tend to decrease. Therefore, if Ontario's environmental protection regulations have decreased pollution intensity, it is possible that productivity performance has been adversely affected in the petroleum refining sector. Regression analysis can guide us on how much confidence to place in this finding.

Exhibit 7.3.4
Correlation Between Productivity and Pollution Discharges in the Petroleum Refining Industry

Pollutant	Productivity vs Discharges per Day	Productivity vs Discharges per Unit of Sales	Productivity Growth vs Discharges per Day	Productivity Growth vs Discharges per Unit of Sales
Suspended Solids	0.06	0.14	-0.01	-0.01
Solvents	0.30	0.32	0.07	0.07
Phenolic	0.40	0.49	0.20	0.23
Ammonia-Nitrogen	0.18	0.08	0.11	0.08

Exhibit 7.3.2
Trends in Productivity and Discharges in the Petroleum Sector

Discharges Per Year



Discharges Per Unit of Sales

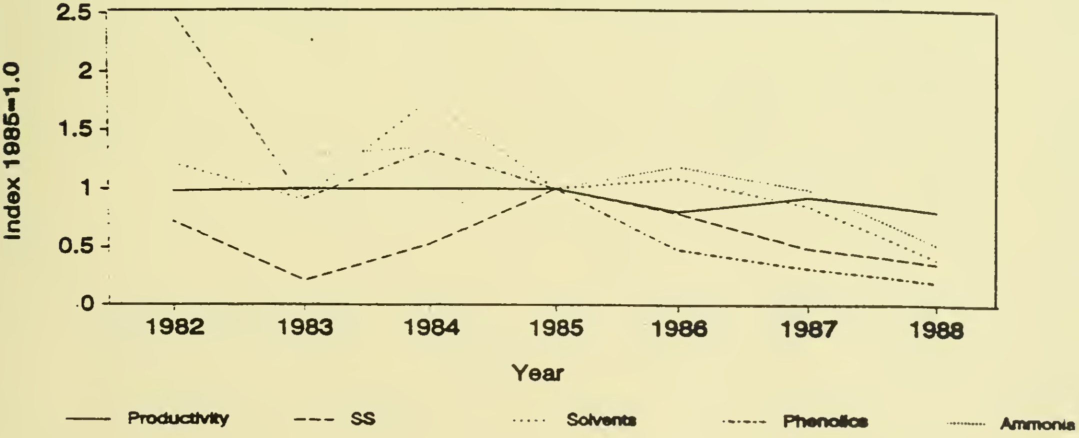
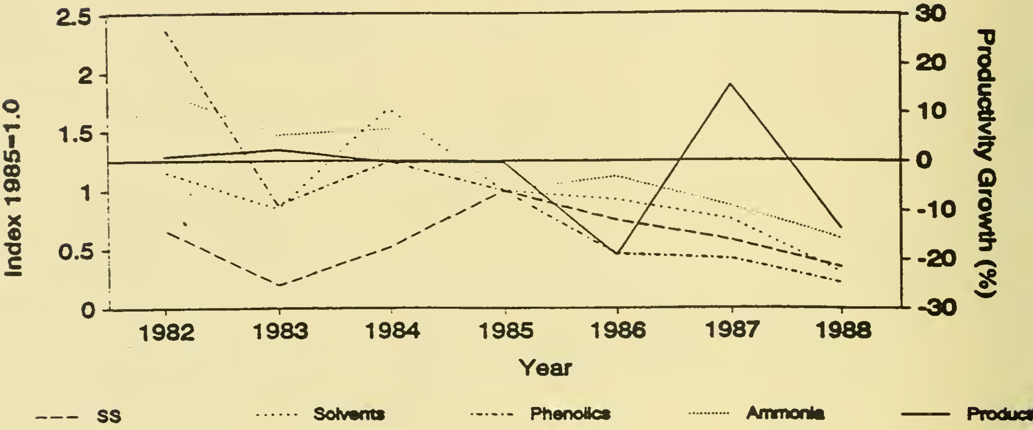
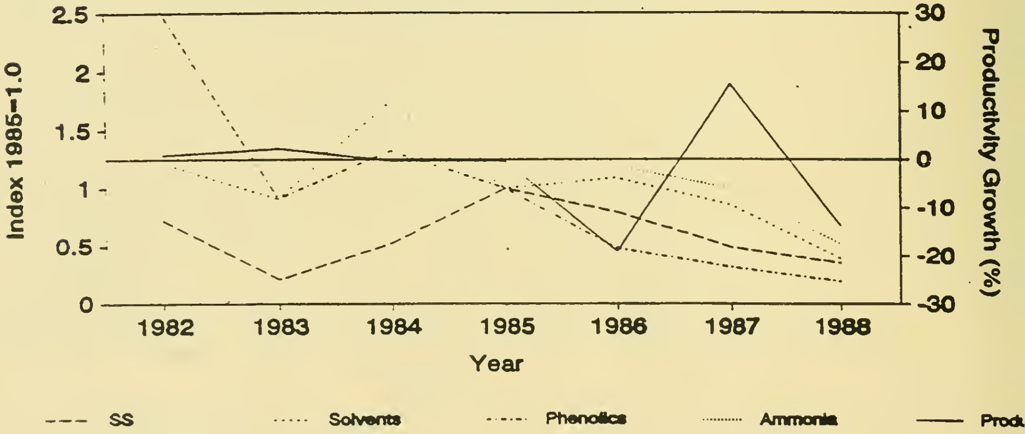


Exhibit 7.3.3
Trends in Productivity Growth and Discharges in the Petroleum Sector

Discharges Per Year



Discharges Per Unit of Sales



Regression Results

The regressions summarized in Exhibits 7.3.5 and 7.3.6 constitute the third analytical tool to assess the productivity impacts of changes in pollution intensity.

Before turning to the results in the tables, two general observations are noteworthy. First, as with the other sectors, dummy variables for each firm and firm-specific time trends were included in the regression equations. Since their interpretation is ambiguous, their estimated coefficients are not included in the tables. However, it is worth noting that these dummies and time trends do not have near the significance as they have in the pulp and paper sector. When these variables are excluded, leaving only capacity utilization, exchange rates and pollution intensity indices as explanatory variables, adjusted R-squared statistics remain above 0.45. Second, attempts to include lagged discharges were unsuccessful due to lack of observations.

Exhibit 7.3.5 presents regression results from equations using productivity as the independent variable. Each equation includes a different index of pollution intensity: annual discharges; discharges per unit of sales; and the natural logarithm of each of these indices.

In general, the equations are highly significant. As indicated by the F-statistic, the probability that the entire set of coefficients are zero is less than 0.1%. The independent variables, including the dummies and time trends, account for roughly three-quarters of the variation in productivity.

Coefficients on capacity utilization are of the expected sign and significant at the 95% confidence level. Exchange rates are highly significant determinants of productivity in the sector.[42]

For three of the four pollutants, coefficients on pollution intensity are positive. This is consistent with the correlation statistics presented above. However, the t-statistics indicate that, at the 95% confidence level, none of these coefficients are significantly different from zero. This means that, despite the sign and magnitude of the estimated coefficient, there is no evidence that productivity and pollution intensity are related.

Exhibit 7.3.6 summarizes a similar set of regressions using productivity growth as the independent variable. Although capacity utilization and exchange rates are significant explanatory variables of productivity growth, the equations as a whole have little explanatory power. The low F-statistics indicate that there is at least a 35% probability that all estimated coefficients are zero. The regressions provide no evidence that pollution intensity is a significant determinant of productivity growth.

In general, then, the regression analysis does not support contentions that productivity or productivity growth in the petroleum refining sector are related to water pollution intensity.

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[42] Despite a fairly high correlation, tests suggest that both exchange rate variables are independently significant.

Exhibit 7.3.5
Regulatory Impacts on Productivity in the Petroleum Refining Sector

Definition of Pollution Intensity Variables	Constant	KUTIL	EXCHI	EXCH2	SS	NH_3	Phenolics	Solvent	Adj R^2	F
D/DAY	-1.8070 (2.07)	0.4608 (2.48)	2.3177 (4.30)	2.4453 (4.20)	-0.00002 (0.34)	0.0010 (1.21)	0.0099 (0.38)	0.0001 (0.58)	0.77	9.94
Log(D/DAY)	-1.7019 (1.95)	0.4577 (2.42)	2.2643 (4.02)	2.2873 (3.66)	-0.0013 (0.35)	0.0008 (0.10)	0.0167 (0.80)	0.0120 (0.70)	0.76	9.60
D/SALES	-2.1601 (2.54)	0.5363 (2.94)	2.4637 (4.80)	2.5933 (4.70)	-0.0002 (0.30)	0.0118 (1.43)	-0.1279 (0.80)	-0.0043 (1.43)	0.79	11.07
Log(D/SALES)	-1.7149 (1.90)	0.4587 (2.41)	2.2966 (3.98)	2.3248 (3.79)	-0.0011 (0.30)	0.0004 (0.05)	0.0149 (0.63)	0.0134 (0.78)	0.76	9.59

D denotes discharges.
Firm-specific dummy variables and time trends are not reported.
t-statistics are given in parentheses.
Shading denotes significance at the 95% confidence level.

Observations: 40
Coefficients: 16

Exhibit 7.3.6
Regulatory Impacts on Productivity Growth in the Petroleum Refining Sector

Definition of Pollution Intensity Variables	Constant	Growth Rate of KUTIL	Change in $Can per $U.S.	Change in $Can per G-10 Index	SS	NH$_3$	Phenolics	Solvent	Adj^2	F
D/DAY	-0.0225 (0.55)	1.0427 (3.36)	1.9001 (1.90)	2.7240 (2.16)	-0.0002 (1.51)	-0.0001 (0.09)	0.0718 (1.22)	-0.0009 (1.41)	0.07	1.18
Log(D/DAY)	0.1427 (0.91)	0.7145 (2.78)	1.0946 (0.85)	2.0638 (1.40)	0.0067 (1.00)	-0.0042 (0.28)	0.0418 (1.04)	-0.0039 (0.12)	0.02	1.06
D/SALES	-0.0209 (0.51)	0.9515 (3.17)	1.9897 (1.95)	2.8132 (2.14)	0.0014 (1.14)	0.0126 (0.75)	0.2151 (0.45)	-0.0083 (1.37)	0.04	1.11
Log(D/SALES)	1.0634 (0.98)	0.7180 (2.86)	1.0493 (0.87)	2.1090 (1.52)	0.0063 (0.94)	-0.0019 (0.12)	0.0545 (1.20)	-0.0008 (0.03)	0.04	1.10

D denotes discharges.
Firm-specific dummy variables and time trends are not reported.
t-statistics are given in parentheses.
Shading denotes significance at the 95% confidence level.

Observations: 35
Coefficients: 16

Impacts on Competitiveness

No estimates of regulatory impacts on the productivity of petroleum refiners in other jurisdictions were found. Therefore, regulatory impacts on relative productivity, this study's measure of competitiveness, are unknown.

7.4 Projected Regulatory Impacts on Productivity and Competitiveness

Projected impacts on productivity are calculated for three scenarios for both the MISA and possible air regulation programs. In the case of MISA, three technology-based scenarios are defined:

- effluent standards achieved at the cleanest Ontario refinery (Nanticoke) coupled with chemical additive substitution (CAS);[43]
- the average concentration performance of the 7 Ontario refineries; and
- effluent standards achieved through the use of chemical additive substitution alone.

Projections are also calculated for the three possible air regulation scenarios, dubbed "most stringent," "medium stringency" and "least stringent." Definitions of the exact technology required by each can be found in Senes (1990).

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[43] Chemical additive substitution involves replacing anti-corrosion additives containing zinc and chromium with other chemicals.

Exhibit 7.4.1
Projected Regulatory Impacts on Productivity in the Petroleum Refining Sector

Regulatory Scenarios	Percent Reduction in Average Productivity
MISA - Nanticoke Flow + CAS	0.07%
MISA - Ontario BPT Flow + CAS	0.05%
MISA - CAS Only	0.01%
Most Stringent Air Regulation Scenario	0.13%
Medium Stringency Air Regulation Scenario	0.10%
Least Stringent Air Regulation Scenario	0.05%

Sources of cost estimates are described in Appendix D.

Using the growth accounting framework, projected decreases in productivity due to MISA and possible air regulation scenarios amount to a small fraction of 1%. If the most stringent options for both air and water regulations are selected, average productivity would decline by an estimated 0.2%.

As in the other two industries examined, it is important to note that these projections assume that compliance expenditures divert inputs from production on a dollar-for-dollar basis. However, in the past, offsetting benefits have resulted from some of the PAC expenditures made by petroleum refiners. Exhibit 7.4.2 provides some examples of realized offsetting benefits in the industry.

If these examples are indicative of revenues and cost savings that result from environmental protection programs, then impacts on productivity estimated using growth accounting principles are overestimated. Unfortunately, no data are available that allow us to calculate to what extent actual impacts might be smaller than those estimated.

Projected regulatory impacts on the productivity of petroleum refiners in other jurisdictions were not available. Therefore, it is unknown to what extent changes in the productivity of Ontario's petroleum refining industry may have on relative productivity.

Exhibit 7.4.2
Examples of Mitigating Factors in the Petroleum Refining Industry

Environmental Problem	**Compliance Strategy**	**Mitigating Factor**	**Magnitude of Mitigating Factor Relative to Compliance Cost**
$S0_2$ Emissions Blue Haze and Odour Around Refineries	Extract sulphur from refinery fuel gases and semi-refined products in sulphur-recovery facilities	Sale of sulphur	Medium- and large-sized refineries can break even (revenue from sale of sulphur roughly covers capital, operating and maintenance costs)
$S0_2$ Emissions	Replace bunker oil with purchased natural gas as major heating fuel	Lower maintenance costs for heaters due to less corrosion	Reduced maintenance costs can usually cover the cost of switching fuels
C0 Emissions	Install special boiler which can burn C0 and produce steam	Supplies large volumes of steam in boiler	In medium and large refineries a pay out usually results
Particulate Matter	Replace Catalytic Cracker catalyst with a more attrition-resistant type	More expensive catalysts can slightly increase gasoline yield	Increased yield (1-2%) is very small relative to increased catalyst costs, but avoids the need to install very expensive control equipment
Disposal of Spent Phenolic Caustic Solution	Segregate spent phenolic caustics and ship to plastics plant	Sale of spent phenolic caustics	Revenue from caustic sales usually cover shipping costs

Medium-sized refinery = daily capacity of approximately 50,000 barrels
Large-sized refinery = daily capacity of 100,000 barrels or more

8.0 Conclusions

Summary

No one study can provide definitive answers to the complex questions regarding industrial competitiveness and environmental regulations. An understanding of the data and methods employed is critical to interpreting the results of any analysis.

With this in mind, we find no clear evidence that the competitiveness or productivity of key Ontario industrial sectors have been impaired by past environmental regulations. Furthermore, projected impacts of possible water and air protection programs on these sector's competitiveness and productivity are likely to be small.

Given its complexity and relevance to policy formation, the topic of regulatory impacts on competitiveness is deserving of on-going research. Specific useful actions include: analysing other measures and determinants of competitiveness; developing an inventory of estimated regulatory impacts on industry in other jurisdictions; and developing more extensive and complete databases to measure regulatory burden.

This study sought to achieve three objectives:

(i) to postulate mechanisms and hypotheses whereby environmental protection regulations affect industrial competitiveness and productivity;

(ii) to test these hypotheses empirically; and

(iii) to forecast the impacts of Ontario's proposed environmental protection measures on the competitiveness and productivity of selected sectors and firms in Ontario.

Fulfilling these objectives is an ambitious undertaking. Assessment of regulatory impacts is very complex and often controversial. No one study can offer the definitive answer as to how environmental protection measures affect the competitiveness and productivity of regulated firms.

This is especially true for assessing regulatory impacts on competitiveness, a concept that is difficult to analyze empirically. For the purposes of this study, relative productivity was selected as the measure of industrial competitiveness. As an operational measure of competitiveness, relative productivity has significant advantages over other possible measures. These advantages include:

- the belief of many prominent analysts that productivity is the primary determinant of competitiveness;
- well developed techniques exist for measuring productivity;
- the existence of numerous analytical frameworks for estimating regulatory impacts on productivity; and
- a relatively large number of existing studies estimating the impacts of environmental protection measures on productivity in foreign jurisdictions.

There are numerous hypothesized channels whereby environmental protection regulations could affect, both positively and negatively, industrial productivity. Firms' compliance strategies could involve numerous changes to inputs, the way in which inputs are transformed into outputs, and outputs. For example, research and development activities, economies of scale and market structure, as well as the use of capital, labour, energy, and materials, could all experience regulatory impacts resulting in productivity changes. Although it occupies a large portion of the debate on regulatory impacts, the full diversion of inputs from "production activities" to pollution abatement and control activities is clearly only one of many ways in which productivity may be affected by environmental regulations.

Testing the historical validity of these hypotheses was highly dependent on data availability. For example, measuring historical regulatory burden was possible only with data on past direct industrial discharges into Ontario waters. Graphs, correlation statistics and regression analysis allow assessment of the relation between pollution intensity indices derived from the discharge data and measures of firm's productivity derived from publicly available financial data.

Although the methodology involves caveats and assumptions that are not ideal, it is consistent with the principles of other productivity studies. Without much better data sources and theoretical advances in the measurement of competitiveness, the methodology used in this study appears to be the best, feasible approach to measuring the impacts of environmental protection regulations on industrial productivity and competitiveness.

Regulatory impacts were examined for three industrial sectors that have been subject to environmental regulations: the pulp and paper industry; the iron and steel industry; and the petroleum refining industry. Little evidence was found to suggest that changes in pollution intensity has affected the productivity performance of these industries in the past. We conclude that any reductions in pollution intensity that have resulted from past environmental regulations have not affected industrial productivity.

The lack of empirical evidence of any regulatory impacts on industrial productivity and competitiveness is consistent with the findings of a recent survey of over 2,300 Canadian firms (Dun & Bradstreet, 1991). The majority of firms in the industry groups corresponding to our sectors of study report no negative effects on their overall competitive positions. Indeed, those that do report negative impacts are equally balanced by those reporting positive impacts. The largest portion of respondents maintain that environmental regulations have had a neutral effect on their competitive position.

A different approach was necessary for projecting the impacts of Ontario's possible air and water regulations. The estimated costs of complying with possible regulatory scenarios provided measures of future regulatory burden. Applying the growth accounting framework to financial-based productivity measures and estimated compliance costs allowed us to project the productivity impacts of Ontario's MISA program and potential air regulations on the productivity of three sectors.

The results indicate that future regulatory impacts on industrial productivity are likely to be small. If the most stringent regulatory scenarios are imposed for both water and air pollutants, the following declines in productivity are possible:

pulp and paper:	0.8%
iron and steel:	1.6% (water only)
petroleum refining:	0.2%

As an indication of the magnitude of these changes, consider that the most stringent combination of air and water regulations would reduce an index of productivity in the pulp and paper industry from 100.0 to 99.2. Such changes are dwarfed by normal cyclical fluctuations in productivity.

When confronted in the past with regulatory requirements, industry has often proven capable of seeking innovative compliance strategies that offer some offsetting benefits. Therefore, the projections should be considered upper bound estimates of future regulatory impacts.

These projections of regulatory impacts should also be considered as just one of the pressures affecting industry. Although in the worst case regulations are expected to reduce productivity by less than 2%, air and water protection programs are not the only forces acting upon firms. For example, environmental regulations pertaining to management of solid and hazardous waste are making demands upon and presenting opportunities to Ontario industry. In this time of restructuring, successful corporate strategies must also consider factors such as increasingly competitive marketplaces, rapidly changing technology, and other government regulations, including those pertaining to management of solid and hazardous waste. Assessing in isolation the impacts of one set of environmental regulations presents only a limited approach.

Given its complexity and relevance to policy formation, the topic of regulatory impacts on competitiveness is deserving of on-going research. In particular, this study recommends the following actions.

- Develop More Extensive Data Sources

  Estimation of the impact of Ontario's environmental protection measures on industrial competitiveness and productivity is very data intensive. It is highly recommended that efforts be devoted to developing more extensive databases on the costs of complying with environmental protection regulations and the magnitude of mitigating benefits derived from these expenditures.

- Develop an Inventory of Estimates of Regulatory Impacts on Industries in Other Jurisdictions

  Defining competitiveness as relative productivity or some other relative term requires that regulatory impacts be compared across jurisdictions. Therefore, an inventory of regulatory impacts on Ontario's competitors is needed. This report begins this process by identifying and summarizing the regulatory impacts estimated in over 40 foreign studies.

- Expand the Analysis to Include Other Measures and Determinants of Competitiveness

  Since competitiveness is such a complex concept, it is important to examine it from many perspectives. Although defining competitiveness as relative productivity is justifiable, it is also limiting. Analysis of regulatory impacts on other measures of competitiveness is recommended.

Appendix A

Annotated References

Appendix A: Annotated References

Aktrin Research Institute (1988) *The Pulp, Paper and Allied Industries in Canada* Oakville: Aktrin Research.

> Aktrin presents a comprehensive overview of the Canadian pulp and paper industry, its historical performance and current position in the domestic and world economy.

Barbera, A. and V. McConnell (1986) "Effects of Pollution Control on Industry Productivity" *Journal of Industrial Economics* 35:2 (December):161-172.

> Four manufacturing industries were examined, namely paper, chemicals, primary metals and stone, clay and glass. The abatement effect on capital and labour productivity are determined by estimating a system of factor demand equations. The system is estimated for each industry with annual time series data from 1960 to 1980. Abatement requirements are found to retard both average capital productivity and average labour productivity in all sectors except the paper sector. For sectors which experienced a significant decline in average capital productivity after 1973, abatement regulations accounted for a large proportion of the slow down.

Barbera, A. and V. McConnell (1990) "The Impact of Environmental Regulations on Industry Productivity: Direct and Indirect Effects" *Journal of Environmental Economics and Management* 18:1 (January):50-65.

> The paper develops an approach to measuring the impact of environmental regulations on total factor productivity growth which is less restrictive than a simple growth accounting approach. Environmental regulations have a direct impact on productivity growth due to the diversion of resources toward required abatement capital. There can be a further indirect effect, however, as conventional inputs and production processes are changed in response to requirements to purchase abatement capital. This indirect effect is estimated using a flexible functional form cost function. Total factor productivity and the direct and indirect productivity effects of environmental regulations are presented for five polluting industries. Depending upon the industry, the estimated indirect effects are either positive or negative, but in all industries is energy-using. The net impact of environmental regulations on total factor productivity growth is fairly small, given that they are the most polluting industries. Environmental regulations account for about 10-30% of the productivity decline of the 1970s in these industries.

Bonsor, N. (1990) "Water pollution and the Canadian Pulp and Paper Industry" in *Getting It Green: Case Studies in Canadian Environmental Regulation* G.B. Doern, ed. Toronto: C.D. Howe Institute, Policy Study 12.

> This paper summarizes the environmental concerns associated with the pulp and paper industry in Canada and provides a brief assessment of the policy options, regulatory and market-based, to reduce the industry's toxic and conventional releases.

Boyd, R. and N.D. Uri (1991) "The Cost of Improving the Quality of the Environment" *Journal of Policy Modeling* 13:1, 115-140.

> This article compares the relative effectiveness of two different methods of meeting the Bush Administration's goals outlined in the Clean Air Plan. The analytical vehicle used in the analysis consists of a computable general equilibrium model composed of 12 producing sectors, 13 consuming sectors, 6 household categories classified by income, a foreign sector, and a

government. They find first, that, irrespective of the type of strategy directed at improving environmental quality that is followed, both output and consumption decline, as does household utility. Hence, there is a quantifiable trade-off between economic growth and the quality of the environment. Beyond this, the aggregate loss in production and economic welfare is less under a policy that stresses reliance on alternative fuels (brought about by taxation) than through one that requires the pollution abatement devices (i.e., regulation).

Campbell, M. and W. Glenn (1982) *Profit from Pollution Prevention* Toronto: Pollution Probe.

This report compiles pollution prevention opportunities for 14 different industries. Emphasis is placed upon pollution prevention activities which generate economic benefits to firms in the form of reduced production costs or new product lines.

Canadian Manufacturers' Association (1991) "The Canadian Competitiveness Index" A Report of the Canadian Manufacturers' Association, Ottawa, September.

This short article measures the "competitiveness gap" between Canada and the other G-7 nations. The index emphasizes the significance of productivity improvements in determining Canadian manufacturing competitiveness.

Canadian Pulp and Paper Association (1990) *Reference Tables, 1990* Montreal: CPPA.

An annual publication reviewing the economic status of the Canadian pulp and paper industry. Statistics are derived primarily from Statistics Canada sources.

Chase Econometric Associates (1972) "The General Economy" in *The Economic Impact of Pollution Control: A Summary of Recent Studies* Washington D.C.: Council on Environmental Quality.

This study was the first commissioned by the U.S. Environmental Protection Agency to employ a macroeconometric model to estimate the macroeconomic impact of environmental protection regulations. The effects were simulated by calculating the percentage increase in production costs faced by major polluting industries, translating these costs into output price increases, adjusting investment patterns while netting out abatement capital from productive capital. Negative impacts occur on GNP and the balance of trade, while unemployment increases. Offsetting government policy can maintain full employment only at the expense of increased inflation.

Christainsen, G. and R. Haveman (1981) "The Contribution of Environmental Regulations to the Slowdown in Productivity Growth" *Journal of Environmental Economics and Management* 8:4 (December):381-390.

This article surveys the literature on the impact of environmental regulations on U.S. aggregate productivity growth and concludes that environmental regulations have likely been responsible for 10% to 12% of the decline in U.S. productivity growth.

Christainsen, G.B. and T.H. Tietenberg (1985) "Distributional and Macroeconomic Aspects of Environmental Policy" in *Handbook of Natural Resource and Energy Economics* Vol. 1, A.V. Kneese and J.L. Sweeney, eds. New York: North-Holland.

This survey article provides a broad review of what is known, and what remains unknown, about the impact of environmental regulations upon the economy. Their review encompasses the effects on regulated industries, households and the aggregate economy. Sectoral effects include economies of scale, market power, research and development and productivity. Macroeconomic evidence of regulatory impacts upon employment and productivity is reviewed. The authors conclude that the aggregate impact of environmental regulations is quite small.

Conrad, K. and C. Morrison (1989) "The Impact of Pollution Abatement Investment on Productivity Change: An Empirical Comparison of the U.S., Germany and Canada" *Southern Economic Journal* 55:3 (January):684-98.

> A modified growth accounting framework is developed and applied to pollution control costs in the United States, Germany and Canada. Results indicate that environmental regulations were responsible for a small decline in the average productivity of Canada and the United States relative to Germany.

Craig, C. and R. Harris (1973) "Total Productivity Measurement at the Firm Level" *Sloan Management Review* 14:3 (Spring):13-30.

> A framework for measuring total factor productivity is developed which assumes that analysts have access to confidential plant level data. The framework is applied to a small U.S. manufacturing firm. The authors argue that partial factor productivities can indicate to managers the trade-offs between employing one resource over another. However, evaluation of managerial efficiency requires a measure of total factor productivity.

Crandall, R.W. (1981) "Pollution Controls and Productivity Growth in Basic Industry" in *Productivity Measurement in Regulated Industries*, T.G. Cowing and R. Stevenson eds. New York: Academic Press.

> Crandall offers a strong critique of standard setting rules which: (i) are based upon engineering standards; or (ii) treat sources more harshly if they are older vintage, part of rapidly growing industries, capital intensive or subject to binding rate-of-return regulation. Using cross-sectional data and a single-equation regression framework, labour productivity is found to have declined most heavily in industries which were subject to more stringent environmental regulations. However, not all other factors were controlled and hence a causal relationship between regulations and productivity decline was not established.

D'Arge (1974) "International Trade, Domestic Income and Environmental Controls: Some Empirical Estimates" in *Managing the Environment: International Economic Cooperation for Pollution Control Estimates* A. Kneese, S. Rolfe and J. Harned, eds. New York: Praeger.

> The ways in which environmental regulations may affect international trade are examined. First, regulations may cause domestic prices to rise, resulting in an increase in imports and a decrease in exports. Second, lower domestic production levels will then reduce domestic income and induce multiplier effects. A preliminary model is developed which illustrates the effects without providing reliable empirical estimates.

Data Resources Inc. (1981) "The Macroeconomic Impact of Federal Pollution Control Programs: 1981 Assessment" A report submitted to the U.S. Environmental Protection Agency, July.

> The study is one of a series of macroeconomic studies commissioned by the U.S. Environmental Protection Agency and Council on Environmental Quality from macroeconometric forecasting firms. Estimates of past and future pollution control costs imposed by EPA regulations form the basis for a policy simulation. The DRI macroeconometric model simulates economic activity under the assumption that EPA regulations were not imposed. Therefore, business investment is reduced by the capital costs of necessitated by regulations, new car prices are reduced reflecting the absence of pollution control equipment, public expenditures are reduced by the amount spent on monitoring and enforcement, etc. The model indicates that, in the absence of regulations, inflation is lower and unemployment is higher. Output during the initial investment phase is lower without regulations, though in later years output would have been higher without regulations.

Davies, J. (1983) "The Effects of Federal Regulation on Chemical Industry Innovation" *Law and Contemporary Problems* 46:3 (Summer):41-58.

The study examines the effects on the U.S. chemical industry of 12 health, safety and environmental statutes. The sector is examined for evidence of increased market concentration, altered research, development and commercialization behaviour. In the absence of a framework which establishes causal links between industry variables and regulations, conclusions are impossible. Suggestions are made for future research.

Davey, T. and T. Bhagat (1979) "A Survey of Financial Resources Devoted to Pollution Control and Environmental Protection in Canada" *Water & Pollution Control* (November/December):39-54.

This article compiles a wide range of empirical data on Canadian environmental expenditures. Data for both private and public sector expenditures are obtained largely from federal and provincial databanks.

Denison E. (1974) *Accounting for U.S. Economic Growth, 1929-1969* Washington, D.C.: Brookings Institute.

This seminal study provided the first major application of the growth accounting framework. Productivity growth in the U.S. nonresidential business sector was assigned to a wide variety of sources in an attempt to explain the sources of economic growth. Since the study did not cover beyond 1969, environmental regulations were largely ignored.

Denison, E. (1984) "Accounting for Slower Growth: An Update" in *International Comparisons of Productivity and Causes of the Slowdown* J.W. Kendrick, ed. Cambridge, Mass.: Ballinger.

Denison employed his growth accounting techniques in a number of studies which encompassed the effects of environmental regulations. For example, results indicate that productivity in 1975 was 1.0 percent lower than it would have been had 1967 pollution control conditions been maintained. In this up-date of his findings, the impact of pollution abatement requirements declined between 1975 and 1978, and were virtually nil after 1978. Of the reduction in productivity growth rate between the periods 1948-1973 and 1973-1981, 0.17 percentage points were attributed to pollution control. An important caveat to all of Denison's work is that *all* recorded pollution control expenditures are assumed to be necessitated by regulations.

Denny, M., M. Fuss and J. May (1981) "Intertemporal Changes in Regional Productivity in Canadian Manufacturing" *Canadian Journal of Economics* 14:3 (August):390-408.

This study investigates the relative efficiency levels and rates of total factor productivity growth in regional Canadian 2-digit manufacturing industries from 1961-1975. Results show that efficiency levels in Ontario exceed those in all other regions except B.C., although the absolute differentials are quite small in most cases. Exceptions are found mainly in the Atlantic region which narrowed the efficiency differential gap during this period.

Denny, M. et al. (1991a) "Changes in Manufacturing Productivity and Competitiveness in Canadian and American Regions, 1975-1985" Working Paper No. 9126, Institute for Policy Analysis, University of Toronto, Toronto, Canada.

This paper provides estimates of productivity growth in the ten most important 2-digit SIC manufacturing industries in selected Canadian provinces and American states. The changes in competitiveness (relative productivity) between American and Canadian regions was quite small.

For any given industry, the Canadian industry did better in some regions and the American industry in other regions.

Denny, M. et al. (1991b) "Productivity In Manufacturing Industries - Canada, Japan and the United States, 1953-1986: Was the Productivity Slowdown Reversed?" Working Paper No. 9128, Institute for Policy Analysis, University of Toronto, Toronto, Canada.

This paper analyzes total factor productivity growth and trends in relative efficiency in the national 2-digit manufacturing industries of Canada, Japan and the United States during the last quarter century. The slowdown in productivity starting in 1973 was evident in all three countries, but was felt most strongly in Japan and least in Canada. Japan and Canada have improved their efficiency levels relative to the U.S. Productivity growth over long periods is determined primarily by advances in the state of knowledge and that advance is highly correlated across countries.

Dun & Bradstreet (1991) "Market Survey of Environmental Expenditures by Canadian Business" Prepared for Environment Canada.

This survey provides data on 1989 environmental expenditures by the Canadian private sector. Expenditures are broken down by major industry, by type of expenditure and by environmental medium (air, water, waste). Results are presented for a wide variety of other questions regarding issues such as regulatory impacts on competitiveness, methods used to finance environmental expenditures, incidence of pollution control equipment.

Ernst & Young (1990) "What Makes a Winner?" *Industry Week* (May 21):30-31.

This article provides a brief introduction to a study of the competitiveness of 277 U.S. manufacturers in the Great Lakes area. The study focuses on the firms' long-term profitability relative to major competitors.

Evans, D. (1986) "The Differential Effect of Regulation Across Plant Size: Comment on Pashigian" *Journal of Law and Economics* 29:1 (April):187-199.

Evans disputes the findings of Pashigian (1984) that environmental regulatory costs have fallen more heavily upon smaller firms than on larger firms. Evans attributes Pashigian's conclusions to faulty statistical analysis and poor reasoning. Instead, Evans claims that smaller firms and establishments benefited from environmental regulations vis-a-vis larger competitors.

Evans, M. (1973) "A Forecasting Model Applied to Pollution Control Costs" *American Economic Review* 63:2 (May):244-252.

Evans combined the Chase macroeconometric model and input-output techniques to estimate the impact of EPA regulations upon the macroeconomy and individual sectors. The methodology employed and the results generated are similar to those described in Chase Econometric Associates (1972).

Farber, K., F. Dreiting and G. Rutledge (1984) "Pollution Abatement and Control Expenditures, 1972-82" *Survey of Current Business* 46:2 (February):22-30.

In addition to providing the up-dates of data on pollution control expenditures compiled by the Census Bureau, the article also estimates their impact on productivity growth. Using a simple growth accounting framework, the costs are estimated to have reduced non-farm business output per labour hours by 0.08 percentage points between 1972-1982.

Furino, A., ed. (1988) *Cooperation and Competition in the Global Economy: Issues and Strategies* Cambridge, Mass.: Ballinger Publishing.

> This collection of articles assesses the major changes taking place in competitive markets and the management strategies available to succeed in the new market environment.

Giarrantani, F. (1974) "Air Pollution Abatement: Output and Relative Price Effects in a Regional Input-Output Simulation" *Environment and Planning A* 6:3 307-312.

> This paper uses direct cost estimates for air pollution abatement developed in an earlier study to derive technical coefficients for several static input-output simulations of abatement activities in West Virginia. Output and relative price effects are calculated for particulate matter abatement and two SO_2 abatement alternatives.

Gold, B. (1976) "Productivity Measurement: Problems and Methods" in *Applied Productivity Analysis for Industry* S. Eilon, B. Gold and J. Soesan, eds. New York: Pergamon Press.

> Gold examines common misconceptions regarding productivity, their sources and possible clarifications to redirect productivity analysis. The sources of many misconceptions are the difficulties in using a concept developed for relatively simple production processes as a measure of the production efficiency of complex manufacturing operations. She focuses upon practical issues in firm-level productivity measurement.

Gollop, F. and M. Roberts (1983) "Environmental Regulations and Productivity Growth: The Case of Fossil-Fuelled Electric Power Generation" *Journal of Political Economy* 91:4 (August):654-74.

> This paper measures and analyzes the effect of sulphur dioxide emission restrictions on the rate of productivity growth in the electric power industry over the 1973-1979 business cycle. A firm-specific measure of regulatory intensity is developed which depends on the severity of the emission standard, the extent of enforcement and the unconstrained emission rate relevant to each utility. The results indicate that emission regulations result in significantly higher generating costs, primarily from the increased use of low-sulphur fuels. The average rate of productivity growth was reduced by 0.59 percentage points per year for regulated utilities.

Gray, W. (1987) "The Cost of Regulation: OSHA, EPA and the Productivity Slowdown" *American Economic Review* 77:5 (December):998-1006.

> Gray estimates a single-equation regression derived from a growth accounting framework in order to determine the impact upon U.S. industrial productivity of EPA and OSHA regulations. Over 30 percent (0.44 percentage points) of the slowdown in productivity growth during the 1970s is attributed to these regulatory activities. Of this effect, 0.17 percentage points were accounted for by environmental protection measures.

Greenberg, Leon (1973) *A Practical Guide to Productivity Measurement* Washington, D.C.: Bureau of National Affairs.

> Greenberg provides an overview on how to develop a corporate productivity measurement program based on firms' financial accounts.

Griliches, Z. (1979) "Issues in Addressing the Contribution of Research and Development to Productivity Growth" *Bell Journal of Economics* 10 (Spring):92-116.

This article provides a critical assessment of current approaches to estimating the impact of R&D on productivity growth.

Griliches, Z. (1988) "Productivity Puzzles and R&D: Another Non-Explanation" *Journal of Economic Perspectives* 2:4 (Fall):9-21.

Griliches tests the hypothesis that declines in R&D expenditures are the cause of the slowdown in U.S. productivity growth during the 1970s, and concludes that R&D can account for no more than 15% of the productivity slowdown.

Hanke, S. and I. Gutmanis (1975) "Estimates of Industrial Waterborne Residuals Control Costs: A Review of Concepts, Methodology, and Empirical Results" in *Cost-Benefit Analysis and Water Pollution Policy* H. Peskin and E. Seskin, eds. Washington, D.C.: The Urban Institute.

Hanke and Gutmanis critically examine empirical studies, all conducted by the U.S. Environmental Protection Agency, on the costs of industrial water pollution programs. The authors identify shortcomings in these studies that suggest much work remains before cost estimates are suitable for policy decision making.

Haveman, R. and G. Christainsen (1981) "Environmental Regulations and Productivity Growth" *Natural Resources Journal* 21:3 (July):489-510.

After reviewing the evidence on the productivity slowdown in the U.S. in the previous two decades, the authors use time series regression analysis to explore the relationship between a measure of U.S. total factor productivity and the intensity of environmental regulations. Regulatory intensity is measured three ways: cumulative number of major pieces of regulatory legislation; the volume of real federal expenditures on regulatory activities; and the number of full-time federal personnel on regulatory agencies. A decline in the productivity growth rate of -0.2 to -0.3 is attributed to regulatory intensity.

James F. Hickling Management Consultants (1990) *The Regulation of Industrial Toxic and Hazardous Emissions in Ontario As Compared With Selected Jurisdictions* Toronto: Ontario Ministry of the Environment.

To determine whether or not Ontario's proposed regulation of toxic effluents and emissions constitute a competitive disadvantage for industries in the province, Ontario's proposed regulations were compared with analogous regulations in Quebec, Alberta, 12 American states and six OECD countries. Given that jurisdictions tend to "leap frog" each other in implementing more stringent regulations, makes it unlikely that regulations will bestow a long term competitive advantage to industry in any of these jurisdictions.

Jones, P. and D. Teece (1988) "The Research Agenda on Competitiveness" in *Cooperation and Competition in the Global Economy: Issues and Strategies* A. Furino, ed. Cambridge, Mass.: Ballinger Publishing Company.

The authors review the state of knowledge of industrial competitiveness and develops a research agenda focusing on the most important knowledge gaps. The agenda places priority on defining the concept of competitiveness.

Jorgenson, D. and L. Christensen (1973) "Measuring Economic Performance in the Private Sector" in *Measurement of Economic and Social Performance* M. Moss, ed. New York: Columbia University Press.

> This long chapter discusses the practical problems in using data on output, inputs, and prices to measure economic performance. A national accounting framework that overcomes many of the problems is presented in detail.

Jorgenson, D. and P. Wilcoxen (1990) "Environmental Regulation and U.S. Economic Growth" *Rand Journal of Economics* 21:2 (Summer):314-340.

> This study employs a general equilibrium model which includes the determinants of long-term economic growth, unusually detailed industrial desegregation and interactions between industries. Environmental regulations are claimed to have reduced annual economic growth by 0.191 percentage points between 1973 and 1985. This impact can be broken down into increased operating costs (-0.034 percentage points), investment effects (0.074), old source investment (0.026) and declining motor vehicle (0.051).

Kalt J. (1988) "The Impact of Domestic Environmental Regulation Policies on U.S. International Competitiveness" in *International Competitiveness* A.M. Spence and H.A. Hazard, eds. Cambridge, Mass.: Ballinger Publishing.

> Kalt employs a Heckscher-Ohlin framework to estimate the relationship between U.S. trade patterns and environmental regulations. Results indicate that regulations had an adverse impact on U.S. trade since the early 1970s, particularly in manufactured goods.

Kohn, R. (1986) "The Rate of Emission and the Optimal Scale of the Polluting Firm" *Canadian Journal of Economics* 14:3 (August):574-581.

> In partial equilibrium competitive models in which emissions are proportional to output, the optimal output of individual firms in a polluting industry is the same with or without a Pigouvian tax. The same holds in general equilibrium only if the production function of those firms is homothetic. The Pigouvian tax increases the price of the polluting goods, reducing industry output and, as a consequence, the relative price of the input in which the polluting firms are relatively intense. They will adjust their input ratios accordingly, and if production functions are non-homothetic, this will either increase or decrease the level of output at which the total profit of the individual firm is zero.

Kohn, R. (1988) "Efficient Scale of the Pollution Abating Firm" *Land Economics* 64:1 (February):53-61.

> The author develops a model that illustrates two scale effects of pollution control requirements. An input effect results from such requirements increasing fixed costs of production. The second effect, the output effect, occurs if the percentage reduction in emissions due to abatement expenditures increases or decreases with output levels.

Kopp, R. and V.K. Smith (1981) "Productivity Measurement and Environmental Regulation: An Engineering-Econometric Approach" in *Productivity Measurement in Regulated Industries* Thomas Cowing and Rodney Stevenson eds. New York: Academic Press.

> This paper develops and estimates a model that implies that productivity frameworks that assume independence of pollution abatement inputs and productive inputs produce biased estimates of the contribution of environmental regulations to the productivity slowdown. Specifically, the model takes into account that all production inputs may be adjusted, not just "pollution abatement inputs," in meeting environmental requirements.

Kunze, K. (1979) "Evaluation of Work-Force Composition Adjustment" in *Measurement and Interpretation of Productivity* Panel to Review Productivity Statistics, National Research Council. Washington, D.C.: National Academy of Sciences.

> This contribution to a larger study assesses the implications of work-force composition for measuring productivity.

Kutscher, R., J. Mark and J. Norsworthy (1977) "The Productivity Slowdown and the Outlook to 1985" *Monthly Labour Review* 100:5 (May):3-8.

> This article describes movements in U.S. labour productivity since 1947, examines some of the major factors associated with productivity trends, and explores the outlook for these factors and their impact on productivity growth in the intermediate future.

Lazar, F. (1991) "An Essay on Competitiveness and Productivity" Mimeo, York University, November.

> Lazar argues that: (i) at the level of the country, competitiveness is a standard of living issue and productivity growth is critical for improving standard of living; and (ii) at the level of the firm, competitiveness and productivity are both determined by the ability of the firm to create and sustain a competitive advantage by succeeding in a sequence of innovation contests.

Lieu, T. (1986) "Impacts of Air Pollution Costs: An Input-Output Approach" *Regional Science* 20:2 (July):55-65.

> This paper uses an input-output framework to evaluate the distributional impacts of four of the most costly NO_x rules on the South Coast Air Basin of California in terms of output, income, employment and prices. The model allows output substitutions by making the household sector endogenous and feeding price elasticities into personal consumption coefficients. The overall results indicate that price impacts are rather insignificant, while increases are recorded in both total output and employment.

Link, A. (1982) "Productivity Growth, Environmental Regulations and the Composition of R&D" *Bell Journal of Economics* 13:2 (Autumn):548-554.

> One factor cited for the decline since the 1960s in average annual productivity growth is the slowdown in the level of R&D spending. Many researchers have examined the correlation between productivity growth and R&D expenditures and found that it was positive through the 1960s but near zero in the 1970s. This latter result has raised the question as to whether the productivity of R&D has collapsed. This article presents evidence that the collapse in the productivity of R&D expenditures is misleading because a significant portion of R&D was directed in the 1970s toward compliance with environmental regulations. These expenditures appear to be negatively related to measured productivity growth.

Magat, W. (1978) "Pollution Control and Technological Advance: A Dynamic Model of the Firm" *Journal of Environmental Economics and Management* 5:1 (March):1-25.

> The paper extends the static comparison of effluent taxes and effluent standards to a dynamic world in which firms invest resources in improving their abatement technology as well as their production technology. The analysis shows that the two pollution control policies lead to a distinctly different allocation of R&D funds between improvements in abatement technology and improvement in production technology. The model also shows that a temporally constant effluent tax leads to an increasing effluent discharge rate for "typical" firms.

Magat, W. (1979) "The Effects of Environmental Regulation on Innovation" *Law and Contemporary Problems* 43:1 (Winter-Spring):4-25.

This paper examines the ways in which various types of environmental measures affect the rate and kinds of innovation produced by firms. The model developed suggests that: (i) technology-based standards provide the least incentive for both abatement technology innovation and output technology diffusion, although they do provide strong incentives for diffusion; (ii) if non-technology-based standards, charges and marketable permits follow a similar dynamic equivalence, all three types of measures provide exactly the same incentive for both abatement technology and output technology innovation; and (iii) if non-technology-based standards, charges and marketable permits are constant over time, their effects on innovation differ in ways too complex to conclude that one policy stimulates more abatement innovation than another.

McCubbin, N., N. Bonsor and D. Owen (1990) "Economic Impact of Proposed Regulation of Pulp and Paper Industry" Report prepared for Environment Canada.

This study assessed the socio-economic impacts of proposed federal regulations on the Canadian pulp and paper industry.

Norsworthy, J.R., M.J. Harper and K. Kunze (1979) "The Slowdown in Productivity Growth: Analysis of Some Contributing Factors" *Brookings Papers on Economic Activity* 2, 423-431.

This study estimates the contribution to the slowdown in U.S. labour productivity growth of, among other variables, growth of pollution abatement capital using a single-equation regression approach. For the period 1973-1978, results attribute a decline of -0.19 to the annual average rate of labour productivity growth.

Panel to Review Productivity Statistics, National Research Council (1979) *Measurement and Interpretation of Productivity* Washington, D.C.: National Academy of Sciences.

This book outlines a comprehensive assessment of productivity measurement in the U.S. The book includes chapters describing the theoretical and practical issues in measuring each component of productivity (labour, capital, etc.), as well as the formulae used to calculate the final productivity. The Panel also provided recommendations for improving U.S. national statistics for measuring productivity and a chapter on measuring productivity at the level of the firm.

Pashigian, B. (1984) "The Effect of Environmental Regulation on Optimal Plant Size and Factor Shares" *Journal of Law and Economics* 27 (April):1-18.

The objectives of this paper are to measure the effects of environmental regulations on the size distribution of plants (i.e., the distribution of industry output by plant size) and on the shares of output distributed to capital and labour (factor shares). Using a regression framework, the study found evidence suggesting that environmental regulations reduced the number of plants in affected industries and placed a greater burden on small plants than on larger plants. A rise in the capital-labour ratio was also attributed to environmental regulations.

Pasurka, C. (1984) "The Short-Run Impact of Environmental Protection Costs to U.S. Product Prices" *Journal of Environmental Economics and Management* 11:4 (December):380-390.

Using an input-output framework, this paper investigates the magnitude of the impact that environmental protection costs had on prices in the United States in 1977. With the imposition of environmental protection costs, the projected total price increases for individual industries ranged from 0.12% to 6.58%. Due to data limitations, the constraints of input-output analysis, and the structural changes that occurred in the economy from 1972 to 1977, the author believes that the results should not be taken as definitive. However, the results are indicative of the typical sort of variation likely to occur across industries and that the average impact on prices was modest.

Pittman, R. (1981) "Issues in Pollution Control: Interplant Cost Differences and Economies of Scale" *Land Economics* 57:1 (February):1-17.

Using a translog production function approach, this study estimates that environmental protection requirements increased the minimum efficient size of pulp mills in Wisconsin, thus increasing barriers to entry and exacerbating any lack of competition in the industry.

Porter, M.E. (1990) "The Competitive Advantage of Nations" *Harvard Business Review* 90:2 (March-April):73-95.

Porter outlines his "Diamond of National Advantage," an approach to assessing competitiveness and how it is achieved. Several case studies illustrate the application of the Diamond.

Porter, M.E. (1991) *Canada at the Crossroads: The Reality of a New Competitive Environment* Ottawa: Business Council on National Issues and Ministry of Supply and Services.

This study applies Porter's "Diamond of National Advantage" to Canada.

Pratten, C. (1976) *Labour Productivity Differentials Within International Companies* Cambridge: Cambridge University Press.

Pratten provides one of the earliest guidelines for measuring productivity at the firm level. Case studies and international comparisons are also included.

Premier's Council (1988) *Competing in the New Global Economy: Volume I* Toronto: Premier's Council of Ontario.

This government report examined the competitiveness of Ontario industry and possible actions to increase competitiveness.

Robison H.D. (1988) "Industrial Pollution Abatement: The Impact on Balance of Trade" *Canadian Journal of Economics* 21:1 (February):187-199.

This paper uses an ex post partial equilibrium framework to measure the impact of marginal changes in industrial pollution abatement costs on the U.S. balance of trade in general, and balance of trade with Canada in particular. The impacts are found to be negative for most industries, growing with trade volume, and small relative to domestic consumption. In addition, some evidence is found that pollution control programs have changed the U.S. comparative advantage such that more high-abatement-cost goods are imported and more low-abatement-costs goods are exported.

Royston, M. (1980) "Making Pollution Prevention Pay" *Harvard Business Review* 58:6 (Nov.-Dec.):6-22.

This paper compiles case studies of firms adopting environmental protection strategies that generated revenue or reduced operating costs.

Senes Consultants Ltd. (1990) "Estimation of the Additional Abatement Costs for the Proposed Revisions to Regulation 308" Prepared for the Ontario Ministry of the Environment.

> This engineering study reviewed the technical options and associated costs for reducing emissions from Ontario industrial sources. Findings are specific to each major industrial sector, for waste disposal companies and for municipalities.

Sharpe, Andrew (1990) "Measurement Problems and Productivity Growth in the Canadian Economy" Canadian Labour Market and Productivity Centre paper presented to a Departmental Seminar at the Department of Economics, Laurentian University, Sudbury, November 22.

> This paper provides a comprehensive overview of issues in measuring productivity growth using Canadian aggregate data.

Sherrard, W. (1967) "Labor Productivity for the Firm: A Case Study" *Quarterly Review of Economics and Business* 7:1 (Spring):49-62.

> Sherrard presents a historical case study of measuring productivity at a U.S. lumber company during the period 1903 to 1938.

Siegel, R. (1979) "Why Has Productivity Slowed Down?" *Data Resources U.S. Review* (March):159-65.

> To determine the sources of the U.S. productivity slowdown, Siegel regresses quarterly output per person hour on the share of manufacturing in total output, relative energy prices, the proportion of prime-age males in the labour force, the capital-labour ratio, and pollution abatement expenditures as a percent of GDP. Results indicate pollution abatement is not a significant determinant of productivity slowdown.

Siegel, I. (1980) *Company Productivity: Measurement for Improvement* Kalamazoo: W.E. Upjohn Institute for Employment Research.

> This short book provides a practical manual for establishing productivity monitoring programs at the company level. Examples of programs implemented at various companies are summarized.

Siegel, I. (1981) "Productivity Measurement at the Firm Level" in *Productivity Analysis at the Organizational Level* N.R. Adam and A. Dogramaci, eds. Boston: Martinus Nijhoff Publishing.

> Siegel surveys definition and measurement issues regarding firm-level productivity measurement programs. Case studies of various approaches are provided.

Sims, W. and J.B. Smith (1983) "The Impact of Environmental Regulations on Productivity Growth" Discussion Paper No. 241, Economic Council of Canada.

> This study examines the impact of extra-strength sewer surcharges on productivity growth in Canadian brewing plants. Evidence from a translog cost function suggests that: (i) surcharges induce a statistically significant reduction of emissions; and (ii) productivity growth is significantly lower in plants subject to surcharges than productivity growth in plants not subject to surcharges.

Statistics Canada (1991a) *Aggregate Productivity Measures: System of National Accounts, 1989* Publication 15-204E.

> This periodic report provides national productivity measures and trends calculated by industry using SNA data.

Statistics Canada (1991b) *Manufacturing Industries of Canada: National and Provincial Areas* Publication 31-203.

> This annual publication provides descriptive data of manufacturing industries by province and industry.

Statistics Canada (1992) "Analysis of the 1989 Pollution Abatement and Control Survey" Ottawa: Capital Expenditures Section, Investment and Capital Stock Division, Statistics Canada.

> This report summarizes the results of a special survey to evaluate the financial involvement of business and social organizations in Canada in their efforts to reduce or eliminate pollutants and wastes released to the environment. The survey measures pollution abatement and control (PAC) expenditures, both capital and operating, for environmental retrofits and new PAC equipment. Additional data on sales and savings arising from PAC expenditures is included.

Sudit, E. (1984) *Productivity Based Management* Boston: Kluwer-Nijhoff Publishing.

> This book presents a thorough review of firm-level productivity measurement and details how such measures can be used as an integral component of company management.

Takeuchi, H. (1984) "Productivity Measurement at the Level of the Firm: An Application Within Food Retailing" in *Productivity Analysis at the Organizational Level* N. Adam and A Dogramaci, eds. Boston: Martinus Nijhoff Publishing.

> Takeuchi provides a detailed case study of measuring and assessing productivity growth at the firm level.

Thurow, L. (1980) "The Productivity Problem" *Technology Review* 83:2 (November/December):40-51.

> This report assessed qualitatively the causes of the slowdown in U.S. productivity growth and concluded that government regulations are only a minor and indirect part of the problem. For mining, regulations likely accounted for about 20% of productivity slowdown, but manufacturing sectors appeared relatively unaffected.

Tobey, J. (1990) "The Effects of Domestic Environmental Policies on Patterns of World Trade: An Empirical Test" *Kyklos* 43:2, 191-209.

> This study provides an empirical test of the hypothesis that stringent environmental policies has caused U.S. trade patterns to deviate in commodities produced by the world's "dirty" industries. Using the cross-section Heckscher-Ohlin-Vanek model of international trade, evidence is found that regulations imposed in the late 1960s and early 1970s by most industrialized countries have not measurably affected international trade.

Ullman, J. (1981) "Measurement of Productivity: Some Open Issues" in *Productivity Analysis at the Organizational Level* N. Adam and A Dogramaci, eds. Boston: Martinus Nijhoff Publishing.

> This article outlines issues in measuring at the firm-level capital inputs and labour inputs and assesses variations for firms producing goods and those producing services.

Victor, P. and T. Burrell (1981) "Environmental Protection Regulation: Water Pollution and the Pulp and Paper Industry" Technical Report No. 14, Regulation Reference, Economic Council of Canada, Ottawa.

> This report reviews water pollution regulations in Canada and the available evidence on how regulations have affected the economic performance of the pulp and paper industry. Through case studies of two Ontario mills, the authors assess the cost effectiveness of selected environmental protection policy options. Limited efforts are also devoted to a quantitative assessment of some potential benefits resulting from discharge reductions in the pulp and paper industry.

Walter, I. (1973) "The Pollution Content of U.S. Trade" *Western Economic Journal* 11:1 (March):61-70.

> This early empirical contribution to the debate on the trade impacts of environmental regulations examined whether environmental control costs were export-biased, import-biased or trade-neutral. Results indicate that regulations are trade-neutral or at worst only marginally biased against U.S. exports.

World Economic Forum (1991) *The World Competitiveness Report: 1990* Lausanne: World Economic Forum.

> This large-scale, annual study compiles for 34 countries data on 330 "competitiveness criteria," that is factors that affect competitiveness. Countries are ranked according to an index of the criteria.

Appendix B

Competitiveness Criteria from the World Competitiveness Report

Appendix B: Competitiveness Criteria from the World Competitiveness Report

Note: Double-weighted criteria are denoted by "*".

Factor I - Domestic Economic Strength
Performance of the Domestic Economy

	Criterion
1.00	**1989 Gross National Product (GNP)** US$ billions at current prices and exchange rates
1.01	**1989 Gross Domestic Product (GDP)** US$ billions at current prices and exchange rates
1.02	**1990 Gross Domestic Product (OECD, ADB)** Provisional US$ billions at current prices and exchange rates
1.03	**1989 Gross Domestic Product at constant prices** US$ billions at 1985 prices
1.04	**1989 GDP per capita** US$ at current prices and exchange rates
1.05	**1989 GDP per capita (PPP)** US$ at current prices and current Purchasing Power Parities
1.06	**Nominal GDP growth** Annual compound percentage change, computed on a local currency basis. 1983-1989
1.07	**Real GDP growth** Annual compound percentage change, computed on a local currency basis at 1985 prices. 1983-1989
1.08	**Real GDP per capital growth** Annual compound percentage change, computed on a local currency basis at 1985 prices. 1983-1989
1.09	**Total gross domestic investment** Gross fixed capital formation as a percentage of GDP. 1986-1989 average
1.10	**Change in gross domestic investment** Annual compound real percentage change, 1985-1989
1.11	**Gross domestic investment** (A) Percentage of GDP. 1988 Machinery and equipment (B) Residential construction
1.12	**Domestic savings*** Gross domestic savings (residents + non-residents) as a percentage of GDP. 1989
1.13	**Parallel economy** Importance of unreported economic activity.
1.14	**Inflation** Rate of inflation compared with main competitors in the next 12 months.
1.15	**Consumer price inflation** Average rate in 1990

Factor I - Domestic Economic Strength
Performance of the Domestic Economy

	Criterion
1.16	**Increase in consumer price inflation*** Average annual increase in inflation 1983-1990
1.17	**Private final consumption expenditure** US$ per capital 1989
1.18	**Real growth in private final consumption expenditure per capital** Annual compound percentage change in local currencies. 1982-1989
1.19	**Forecasts for 1991 (OECD, ADB, EIU)** (A) GDP - Real % change (B) Private consumption - Real % change (C) Gross fixed investment - Real % change (D) Inflation - % change (E) Unemployment - % of total labour force (F) Current balance % of GDP/GNP
1.20	**Accuracy of official government forecast in mid-term** As evaluated by executives.
1.21	**Expected growth in industry for 1991** As evaluated by executives
1.22	**Economic flexibility** Effectiveness of the economy in shifting resources from declining to new industries.
1.23	**Recession** Likelihood of a severe recession over the next 2 years.
1.24	**Importance of industrial production** Percentage of GDP in 1988
1.25	**Real growth in industrial production.** 1989. seasonally adjusted. 1980 = 100
1.26	**Capital goods** Percentage of total manufacturing output. 1987
1.27	**Growth in production of capital goods** Annual compound percentage change. 1980 - 1989
1.28	**Crude steel production** Annual average per capital in kg. 1987 - 1989
1.29	**Chemicals** Percentage of total manufacturing output. 1987
1.30	**Growth in production of chemical** Annual compound percentage change: 1980 - 1988
1.31	**Cement production** Annual average per capital in kg. 1986 - 1989
1.32	**Size of the service sector** Percentage of GDP in 1988
1.33	**Real growth in services** Average annual percentage rate of growth. 1980-1988

Factor I - Domestic Economic Strength
Performance of the Domestic Economy

	Criterion
1.34	**Retail sales*** US$ per capital. 1988
1.35	**Real growth in retail sales** Real annual compound percentage change in local currency 1983 - 1989
1.36	**Agricultural productivity** Value added per capital in current dollars. 1988
1.37	**Growth in food production** Food production per capital (1979 - 1981 =100). 1985 - 1+99 average

Factor II - Internationalization
Participation in the International Economy

	Criterion
2.01	**Balance of merchandise trade** (A) US$ billions. 1989 (B) Percentage of GDP. 1989
2.02	**Terms of trade index**[*] Unit value of exports over unit value of imports. 1983 - 1989 average (1985 = 100)
2.03	**Balance of trade in total services** (A) US$ billions. 1989 (B) Percentage of GDP. 1989
2.04	**Current account balance** (A) US$ billions. 1989 (B) Percentage of GDP. 1989
2.05	**Import coverage** Number of months of average merchandise imports covered by total official reserves. 1989
2.06	**Increased trade dependency** Annual compound percentage growth of imports divided by growth of exports. 1982 - 1989
2.07	**Trade legislation** Conduciveness of trade policies in developing long-term competitiveness
2.08	**Exchange rate index**[*] Average trade - weighted real value of each currency. (December 18. 1971 = 100). 1990
2.09	**Exchange rate stability** Parity change from national currency to SDR. 1989 over 1982.
2.10	**Exchange rate policy** Effectiveness of exchange rate policy in encouraging international competitiveness of firms in a country.
2.11	**Exports of goods and services** (A) US$ millions. 1989 (B) Percentage of GDP, 1989
2.12	**Growth in exports of goods and services** Annual compound percentage change based on US$ export values. 1982 - 1989
2.13	**Exports of selected products (US$ billions. 1989)** (A) Manufactured goods (B) Engineering products (C) Agricultural products (D) Total services (E) Commercial services
2.14	**Exports of manufactured products** Percentage of merchandise exports. 1989
2.15	**Exports of engineering products** Percentage of total exports of manufactured goods. 1989
2.16	**Growth in the value of merchandise exports** Annual compound percentage change based on US$ export values. 1982- 1989
2.17	**Growth in the volume of merchandise exports** Annual compound percentage change. 1983 - 1989

Factor II - Internationalization
Participation in the International Economy

	Criterion
2.18	**Growth in exports of services** annual compound percentage change, based on US$ export values. 1982 - 1989
2.19	**Diversification index for commodity exports** Absolute deviation of commodity export share from world structure. 1986
2.20	**Export market diversification** Percentage of export market value dominated by top 3 destination countries. 1988
2.21	**Export flexibility** Adaptability of domestic products for export.
2.22	**Imports of selected products (US$ billions. 1989)** (A) Total goods & services (B) Commercial services (C) Manufactured goods (D) Engineering products (E) Agricultural products (F) Fuels
2.23	**Growth in the value of merchandise imports** Annual compound percentage change based on US$ import values. 1982 - 1989
2.24	**Growth in volume of merchandise imports** Annual compound percentage change. 1983 - 1989
2.25	**Imports of manufactured goods** Percentage of merchandise imports, by value (US$ billions). 1989
2.26	**Growth in value of services imports** Annual compound percentage change based on US$ import values. 1982 - 1989
2.27	**Growth in value of merchandise and services imports** annual compound percentage charge based on US$ import values. 1982 - 1989.
2.28	**Tourism receipts (Tourism receipts from abroad, 1990)** (A) US$ billions (B) Percentage of GDP
2.29	**Direct investment flows abroad** US$ billions. 1989
2.30	**Direct investment flows abroad** Percentage of gross fixed capital formation. 1986 - 1989 average
2.31	**Direct investment stocks abroad** US$ billions. 1989
2.32	**Direct investment flows inward** US$ billions. 1989
2.33	**Direct investment flows inward** Percentage of gross fixed capital formation. 1986 - 1989 average
2.34	**Direct investment stocks inward** US$ billions. 1989
2.35	**Tendency to import** Import elasticity. i.e. percentage change in the volume of imports divided by percentage change in real GDP growth. 1983 - 1989

Factor II - Internationalization
Participation in the International Economy

	Criterion
2.36	**Foreign acquisitions** Freedom of foreign investors to acquire a controlling interest in domestic companies.
2.37	**Foreign investment at home** Acceptance of foreign investment.
2.38	**Partnership with foreign firms** Extent to which government allows companies to negotiate joint ventures with foreign partners.
2.39	**National protectionism** Freedom to import products without protectionist barriers.
2.40	**Expatriate work permits** Ease with which foreign executives obtain temporary work permits.
2.41	**Export performance** Export volume growth relative to market growth. 1988 - 1991
2.42	**Exports credits and insurance** Availability of reasonably priced export credits and insurance.
2.43	**International alliances** Willingness of domestic firms to enter into cross-border alliances.
2.44	**Overseas postings** Extent to which managers are willing to accept postings abroad.
2.45	**Government support for investing abroad** Extent government supports and facilitates internationalization of companies.
2.46	**Official Development Assistance (ODA)** Net disbursements as a percentage of GDP. 1986 - 1989 average

Factor III - Government
Impact of the State on the Economy

	Criterion
3.01	**Central government total debt** (A) US$ billions. 1989 (B) Percentage of GDP. 1989
3.02	**Central government domestic debt** (A) US$ billions. 1989 (B) Percentage of GDP. 1989
3.03	**Central government foreign debt*** (A) US$ billions. 1989 (B) Percentage of GDP. 1989
3.04	**Total external debt** US$ millions. 1989
3.05	**Budget surplus/deficit, consolidated central government** (A) US$ billions. 1989 (B) Percentage of GDP. 1989
3.06	**Total official reserves** Including gold US$ billions with gold at SDR 35 per ounce, converted from SDRs (US$ = SDR 0.76092) end 1989
3.07	**Gold reserves** US$ millions, fine troy ounces converted at London gold price (40) US$/ounce). end - 1989
3.08	**Government employment** Percentage of total employment 1988
3.09	**State Ownership** Extent to which state ownership of businesses is determined to competitiveness.
3.10	**State enterprise autonomy** Extent of autonomy in management decisions in state-owned enterprises.
3.11	**Military expenditure** (A) US$ millions. 1988 (B) Percentage of GDP, 1988
3.12	**Regulatory environment** Extent to which the conduct of business is free from bureaucratic constraints.
3.13	**Non-productive investment** Pressure on enterprises to make investments that are not oriented towards increase in production.
3.14	**Agricultural policies** Extent to which agricultural policies are based on long-term economic concerns.
3.15	**Environmental protection** Extent to which environmental issues are adequately addressed.
3.16	**Indicators of monetary stability (Annual compound percentage change. 1983 - 1989)** (A) National GDP (B) Inflation (C) Money supply (M2)
3.17	**Government final consumption expenditure** Percentage of GDP. 1989

Factor III - Government
Impact of the State on the Economy

	Criterion
3.18	**Government final consumption expenditure** Percentage of GDP, annual percentage change. 1983 - 1989
3.19	**Total tax revenues** Including social security contributions as a percentage of GDP. 1989
3.20	**Change in total tax revenues** Percentage of GDP, annual compound percentage change. 1983 - 1989
3.21	**Capital and property tax revenues** Revenues from taxes on capital and property as a percentage of total tax revenues. 1986
3.22	**Personal income tax** On profits, income and capital gains, as a percentage of GDP. 1988
3.23	**Personal Taxes** Impact on discouraging individual work initiative.
3.24	**Top income taxes** Top percentage marginal tax rate or personal income, effective for most of 1990.
3.25	**Corporate taxes** On profitable income and capital gains, as a percentage of GDP. 1989
3.26	**Corporate income tax rates** Percentage rates in effect for most of 1990.
3.27	**Corporate income after tax** From property and entrepreneurial activities as a percentage of GDP. 1985 - 1988 average.
3.28	**Indirect tax revenues**[*] Taxes on goods and services, as a percentage of GDP. 1989
3.29	**Employer's social security contributions** Percentage of GDP. 1989
3.30	**Employee's social security contributions** Percentage of GDP. 1989
3.31	**Effectiveness of fiscal policy** Extent to which corporate investment is encouraged.
3.32	**Effectiveness of fiscal policy** Extent to which entrepreneurial activity is encouraged.
3.33	**Fiscal treatment** Equitable treatment of all enterprises under law.
3.34	**Anti-trust laws** Effectiveness of anti-trust laws.
3.35	**Dominant position** Extent to which dominance of a limited number of enterprises hinders new business development.
3.36	**Resource allocation** Effectiveness of government in promoting competitive business.
3.37	**Government economic priorities** Extent to which government policies favour investment and growth rather than distribution of wealth.

Factor III - Government
Impact of the State on the Economy

	Criterion
3.38	**Lobbying** Extent to which lobbying accelerates government decision-making.
3.39	**Pricing** Freedom of companies to set competitive prices.
3.40	**Price distortion by government subsidies** Extent of price distortions caused by government subsidizing.
3.41	**Public sector contract** Openness of public sector procurement to foreign competitors.
3.42	**Government subsidies to private and public enterprises** Percentage of GDP. 1989
3.43	**Free flow of credit** Extent to which government permits the free flow of credit to business.
3.44	**Profit distribution** Freedom of management to reinvest profits as preferred.
3.45	**Managerial freedom** Extent to which management is free to allocate corporate assets as preferred.
3.46	**Managerial flexibility in employment** Flexibility of management to adjust employment levels during difficult periods.
3.47	**Bankruptcy laws** Effectiveness of bankruptcy laws in helping troubled firms reorganize.
3.48	**Financial failure** Extent to which sanctions and public opinion discourage individual risk taking and entrepreneurship.
3.49	**Support for government policies** Public consensus and support for economic policies.
3.50	**Voter turnout** Percentage of eligible voters participating in most recent general election.
3.51	**Justice** Confidence in the fair administration of justice.
3.52	**Security** Respect society has for the security of people and property.
3.53	**Expropriation** Confidence that private assets are free from arbitrary expropriation.
3.54	**Serious crime** Number of murders, violent crimes or armed robberies reported. 1987 - 1989 average
3.55	**Terrorism** Threat of terrorism to politico-social stability.
3.56	**Improper practices** Extent to which government regulations prevent improper practices in the public sphere.
3.57	**Equal opportunity** Equal opportunity of individuals in life regardless of race, sex or family background.

Factor III - Government
Impact of the State on the Economy

Criterion	
3.58	**Values** Extent to which values of a society support competitiveness (such as hard work, tenacity, loyalty)
3.59	**Government responsiveness** Ability to quickly adapt policies to new economic realities.
3.60	**Administrative decentralization** Decision-making independence of local/regional authorities from central government.

Factor IV- Finance
Availability of Finance

	Criterion
4.01	**Country credit rating** Rating on a scale of 0-100 assessed by the Institutional Investor Magazine. September 1990
4.02	**Real short-term interest rate*** Average real prime rate January-December 1990
4.03	**Selected interest rates** (A) Price rate - Average nominal prime rate. January - December. 1990 (B) Discount rate/bank rate - End-1990 in percent per year (C) Money market rate - 1990 average in percent per year. (D) Deposit rate - 1990 average in percent per year (E) Lending rate - 1990 average in percent per year (F) Government band yields - Average yields in maturity in percent per year. 1990
4.04	**Financial alternatives** variety of financial alternatives available to business.
4.05	**Access to local capital markets** Access to local capital market by foreign companies compared to that of domestic companies.
4.06	**Financial deregulation and service industries** Effectiveness of banking and financial service industries in exploiting deregulated markets globally.
4.07	**Stock market capitalization** US$ per capital. 1990
4.08	**Performance of international stock markets** 1990 percentage change.
4.09	**Share issues** Total share issues expressed as a percentage of GDP. 1989
4.10	**Price/earnings ratio** Based on net earnings to ordinary shareholders. 31 December 1990
4.11	**Funds raised on international markets** (A) US$ billions. 1989 (B) Percentage of GDP. 1989
4.12	**Domestic bond issues** Percentage of GDP. 1989
4.13	**International bond issues** Percentage of GDP. 1989
4.14	**Corporate bond issues** By public and private non-financial enterprises as a percentage of total national issues. 1989
4.15	**Risk capital** Availability of risk capital
4.16	**Factoring - International factoring. 1990** (A) US$ million (B) Percentage of GDP
4.17	**Cross-border financial flows** Extent to which capital is allowed to flow freely.
4.18	**Size of banks** Number of banks among the world's top 500, ranked by assets. 1989

Factor IV- Finance
Availability of Finance

	Criterion
4.19	**Banks as a source of credit to private sector** Commercial bank claims on the private sector. Percentage of total domestic credit (in local currencies). 1989
4.20	**Relationships with banks** Conduciveness of the banking sector to business development.
4.21	**Private-sector borrowing** Difficulties of private sector compared to public (government) sector in borrowing.
4.22	**Depreciation** Extent to which amortization of fixed assets encourages growth.

Factor V - Infrastructure
Availability and Efficient Utilization of Natural Resources

	Criterion
5.01	**Arable area** Square meters per capital. 1988
5.02	**Total indigenous production - Kg per capital. 1986 - 1989 average** (A) tin (B) molybdenum (C) nickel (D) lead (E) zinc (F) bauxite (G) copper
5.03	**Coal production** Kg per capital. 1987 - 1989 average.
5.04	**Total indigenous energy** Percentage of total requirements in tons of oil equivalent. 1988
5.05	**Crude petroleum production** Kg per capital. 1987 - 1989 average.
5.06	**Natural gas production** Megajoules per capital. 1987 - 1989 average.
5.07	**Electricity generation** Kwh per capital annual average production. 1987 - 1989
5.08	**Hydro-electric and thermal energy production** Production as a percentage of total energy requirements. 1988
5.09	**Nuclear generated electricity** Electricity generated by nuclear power reactors in 1988, as a percentage of total electricity generation.
5.10	**GDP and energy consumption** GDP growth minus energy consumption growth. 1982 - 1988 average
5.11	**Change in energy consumption** Annual compound percentage change in megatons of oil equivalent. 1982 - 1988
5.12	**Energy intensity** Amount of commercial energy consumed for each dollar of GDP 1988 kilojoules
5.13	**Enterprises' share of energy consumption** Percentage of total final energy consumption. 1988
5.14	**Net imports of oil and oil products** Ratio to total oil and oil products demand. 1988
5.15	**Change in net imports of oil** annual average percentage rate of growth in net imports in tons of oil equivalent. 1982 - 1988
5.16	**Energy imports vs merchandise exports** Energy imports as a percentage of merchandise exports in USS. 1989
5.17	**Self-sufficiency in non-energy raw materials** Per capital trade balance in USS. 1988
5.18	**Domestic natural resources** Adequacy of domestic natural resources

Factor V - Infrastructure
Availability and Efficient Utilization of Natural Resources

	Criterion
5.19	**Imported natural resources** Vulnerability of the country to shortages in critical imported resources.
5.20	**Substitution of scarce resources** Success of companies in developing commercially feasible substitutes for scarce resources.
5.21	**Recycling of resources** Extent of recycling of resources by companies.
5.22	**Resource management by government** Effectiveness of government in managing the use and allocation of public (government-owned) natural resources.
5.23	**State investment in telecommunications** Percentage of GDP. 1985 - 1988 average
5.24	**Telephones** Number in use per 1,000 inhabitants. January 1, 1989
5.25	**Facsimile machines** (A) Number of facsimile machines exported by Japan in 1990 (local market for Japan) (B) Purchase per 10,000 inhabitants
5.26	**International telex traffic** Outgoing traffic in minutes per capital 1989
5.27	**Electronic Data Processing (EDP)** (A) Production of EDP equipment. 1989 - US$ millions (B) Size of the domestic market. 1989 - Purchases of EDP equipment. US$ millions.
5.27	**Office Equipment** (A) Production of office equipment. 1989 US$ millions (B) Size of the domestic market. 1989 - Purchases of office equipment. US$ millions
5.27	**Telecommunications** (A) Production of telecommunications equipment. 1989 US$ millions (B) Size of the domestic market. 1989 - Purchases of telecommunications equipment. US$ millions
5.28	**Infrastructure requirements - Extent to which infrastructure meets business requirements** Roads
5.29	**Infrastructure requirements - Extent to which infrastructure meets business requirements** Railroads
5.30	**Infrastructure requirements - Extent to which infrastructure meets business requirements** Air transport
5.31	**Infrastructure requirements - Extent to which infrastructure meets business requirements** Port access
5.32	**Infrastructure requirements - Extent to which infrastructure meets business requirements** Telecommunications
5.33	**Infrastructure requirements - Extent to which infrastructure meets business requirements** Power supply
5.34	**Utility costs for industrial clients** (A) International telephone costs - US$ per 3 minutes. 1990 (B) Electricity - US$ per kwh. 1990 (C) Water - US$ per cubic meter. 1990
5.35	**Efficiency of retail and distribution systems**

Factor V - Infrastructure
Availability and Efficient Utilization of Natural Resources

Criterion	
5.36	**Power of the wholesaler** Wholesaler's control over nature, quality, availability and price of products.

Factor VI - Management
Entrepreneurial Drive and Quality of Management

	Criterion
6.01	**New business generation** Rate of new business generation during the next two years as expected by executives.
6.02	**Plant and equipment maintenance** Level of reinvestment in production facilities.
6.03	**Managerial initiative** Sense of entrepreneurship, drive and responsibility of managers.
6.04	**Long-term objectives** Emphasis on the long term in strategic decision-making.
6.05	**Managerial willingness to delegate** Managers' willingness to delegate authority to subordinates.
6.06	**Management and information technology.** Utilisation of and familiarity with information technology by management.
6.07	**Corporate credibility** Public trust on business community.
6.08	**Social needs and corporate boards** Extent to which corporate boards balance social and business needs.
6.09	**Business and law** Degree of understanding, enforcement and acceptance of legal rights and business regulations.
6.10	**Product quality** Domestic products rated by executives.
6.11	**Product design, style and packing** Domestic products rated by executives.
6.12	**Product safety** Domestic products rated by executives.
6.13	**After-sales service** Domestic products rated by executives.
6.14	**Competitive pricing** Domestic products rated by executives.
6.15	**Marketing orientation** Extent to which domestic companies are marketing oriented compared to their international competitors.
6.16	**Advertising expenditure** US$ per capital 1989
6.17	**Overall productivity*** GDP per person employed in USS, 1989
6.18	**Change in overall productivity*** Annual compound percentage change of real GDP per person employed. 1983 - 1989
6.19	**Productivity in manufacturing** Manufacturing value added per manufacturing worker in USS, 1987
6.20	**Manufacturing unit labor costs*** Local currency. 1989, 1987

Factor VI - Management
Entrepreneurial Drive and Quality of Management

	Criterion
6.21	**Manufacturing unit labor costs - as an estimate by OECD** Local currency. 1990, 1987
6.22	**Corporate profits** Likelihood of improvement in corporate performance (return on equity in 1991)
6.23	**Size of industrial corporations** Number of Fortune 500 industrial companies (ranked by sales) based in a country.
6.24	**Rise in machinery and equipment prices** Average annual increase. 1980 - 1988
6.25	**Compensation levels** Total hourly compensation for manufacturing workers (wage plus supplementary benefits in USS. 1989
6.26	**Remuneration of CEO's and CFO's** Total annual remuneration of a chief executive officer (CEO)/chief financial officer (CFO) (1) USS thousands. January 1, 1990.
6.27	**Remuneration of CEO's and CFO's** Total cash remuneration of a CEO/CFO(2) US CEO = 100 January 1,1990.
6.28	**Remuneration of CEO's and CFO's** Purchasing Power of a CEO/CFO (3) US CEO = 100. January 1, 1990.
6.29	**Change in manufacturing earnings** Total hourly compensation paid by employer annual compound percentage change. 1983 - 1989. Local currency (current prices)
6.30	**Change in manufacturing earnings** Total hourly compensation paid by employer annual compound percentage change. 1983 - 1989. (B) Local currency (real terms)
6.31	**Labor absenteeism** Impact of labor absenteeism on business.
6.32	**Labor absenteeism in manufacturing industries** Workdays lost per manufacturing worker. 1990
6.33	**Safety at Work** Absenteeism due to work accidents and injuries
6.34	**Employee turnover** Rate of employee turnover.
6.35	**Hourly compensation in selected manufacturing sectors** USS. 1989 (A) Chemical and allied products (B) Rubber products (C) Fabricated metal products (D) Non-electrical machinery (E) Electrical & electronic equipment (F) Transportation equipment

Factor VI - Management
Entrepreneurial Drive and Quality of Management

	Criterion
6.36	**Monthly wages in selected service professions** US$. 1989 (A) Banking: bank teller (B) Insurance computer programmer (C) Public administration office clerk (D) 1st level education: teacher (E) Medical profession nurse
6.37	**Information technology** Utilization of computer-based information technology.
6.38	**Electronic Data Interchange (EDI)** Effective use of EDI, connecting a company's computer system to other enterprises and organizations.
6.39	**Industrial robots** Population end 1989
6.40	**Labor-saving technology** Receptiveness of labor force in automation.
6.41	**Pressure groups** Freedom from public pressure in business development (e.g. biotechnology, nuclear energy)
6.42	**Product liability** Extent to which product liability legislation restrains new product development or increases cost of product development.

Factor VII - Science and Technology
R & D Expenditure

Criterion

7.01 **Total expenditure on R&D**
(A) US$ millions, 1989 (1)
(B) Percentage of GDP, 1989

7.02 **Growth in total expenditure on R&D**
Annual compound percentage growth. 1983 - 1989 (1)

7.03 **Total R&D expenditure in manufacturing**
US$ millions

7.04 **R&D expenditure by selected manufacturing activities**
Percentage of manufacturing R&D (1)
(A) Electric.
(B) Machinery
(C) Transport
(D) Basic metals
(E) Food, drink and tobacco
(F) Textiles and clothing
(G) Chemicals and related
(H) Pharmaceutical

7.05 **Business expenditure on R & D**
(A) US$ millions, 1989 (1)
(B) Percentage of total R&D expenditure. 1989

7.06 **Business R&D expenditure by economic sector**
Percentage of total R&D expenditure (1)
(A) Agriculture
(B) Mining
(C) Manufacturing
(D) Public utilities and construction
(E) Services

7.07 **Real growth in business R&D expenditure**
Annual real compound percentage change. 1983 - 1989 (1)

7.08 **Future F&D spending**
Growth rate of business R&D spending relative to inflation in the next two years.

7.09 **Private funding of business R&D**
US$ millions. 1989 (1)

7.10 **Public funding of total R&D**
Percentage of total R&D funded by the state. 1989

7.11 **Public funding of business R&D**
(A) US$ millions. 1989 (1)
(B) Percentage of total business R&D. 1989

7.12 **Public funding of non-defense R&D**
Percentage of government R&D allocated to non-defense research. 1989

7.13 **Total R&D personnel nationwide**
Full-time work equivalent. 1989 (1)

7.14 **Total R&D personnel nationwide**
Per 1,000 of the labor force. 1988

7.15 **Growth of R&D personnel nationwide**
Annual compound percentage rate. 1983 - 1988 (1)

Factor VII - Science and Technology
R & D Expenditure

	Criterion
7.16	**Number of scientists and engineers (university graduates) in R&D** (A) Full-time work equivalent. 1988 (B) Percentage of total R&D personnel. 1988
7.17	**Total R&D personnel in industry** (A) Full-time work equivalent. 1988 (B) Percentage of R&D total personnel. 1988
7.18	**Growth of total R&D personnel in industry** Annual compound percentage change. 1983 - 1988
7.19	**R&D scientists & engineers (university graduates) in industry** (A) Total number of scientists and engineers in industry. 1988 (B) Percentage of nationwide total. 1988
7.20	**Nobel prizes** Number awarded in physics, chemistry, physiology or medicine and economics. 1950 - 1990
7.21	**Number of patents in force** (A) Total (thousands) 1989 (B) Per 100,000 inhabitants, end 1989
7.22	**Patents granted to residents** Average annual number of patents granted to residents per 100,000 inhabitants. 1986 - 1989
7.23	**Change in patents granted to residents** Annual compound percentage change. 1981 - 1989
7.24	**Number of patents granted in the USA** By country of origin 1989
7.25	**Patents granted to non-residents** Ratio granted to non-residents 1986 - 1989 average
7.26	**Change in patents granted to non-residents** Annual compound percentage change in number of patents granted to non-residents. 1986 - 1989
7.27	**Securing patents abroad** Number of patents secured abroad by country residents, per 100,000 inhabitants. 1989
7.28	**Change in securing patents abroad** Annual compound percentage change in the number of patents secured abroad by residents. 1985 - 1989
7.29	**Patent balance** Annual compound percentage change between patents secured overseas and domestic patents granted to non-residents. 1985 - 1989
7.30	**Protection of intellectual property** Effectiveness of intellectual property legislation.
7.31	**Search for technology** Ability of companies to seek out and exploit new technologies and process world-wide.

Factor VII - Science and Technology
R & D Expenditure

Criterion

7.32 **Patents granted by sector and industry**
Ratio of patents granted to residents/total number of patents granted. 1989
- (A) Agriculture, foodstuffs & tobacco
- (B) Personal & domestic articles, health & amusement
- (C) Performing operations (separating, mixing, shaping and printing)
- (D) Transporting
- (E) Chemistry
- (F) Metallurgy
- (G) Textiles and paper
- (H) Mechanical engineering
- (I) Lightning and heating
- (J) Physics (instrument)
- (K) Electricity

7.33 **Patents granted**
Number of patents granted in 1989

7.34 **Linking R&D efforts**
Level of cooperation between enterprises on R&D.

7.35 **Basic research**
Effectiveness of basic research in meeting the long-term needs of the economy.

7.36 **University research programs**
Access business has to university R&D programs.

Factor VIII - People
Population Characteristics

	Criterion
8.01	**Population size** Estimates in millions, mid 1989
8.02	**Population density** Number of inhabitants per square kilometre 1989.
8.03	**Population growth** Annual compound percentage change. 1983 - 1989
8.04	**Population and economic growth** Impact of size and growth of population on competitiveness.
8.05	**Population structure** Impact on population structure on competitiveness.
8.06	**Population under 15 years** Percentage of total population. 1988
8.07	**Population over 65 years** Percentage of total population. 1988
8.08	**Life expectancy at birth** Average estimates for the period 1990 - 1995
8.09	**Compulsory education** Effectiveness of compulsory education system in meeting the demands of a competitive economy.
8.10	**In-company training** Effectiveness of in-company training programs in meeting the needs of competitive economy.
8.11	**Public expenditure on education*** (A) Total USS millions. 1988 (B) USS per capital. 1988
8.12	**Secondary school enrolment** Percentage of relevant age group receiving full-time education. 1987
8.13	**Secondary school attainment** Percentage of population which has completed, but not exceeded a secondary schooling level. 1987
8.14	**Higher education enrolment** Percentage of 20-24 year-old population enrolled in higher education. 1987
8.15	**Higher education attainment** Percentage of population which has completed last level one university degree. 1987.
8.16	**Illiteracy** Adult (over 15 years) illiteracy rate Percentage of population
8.17	**Economic literacy** Level of economic literacy among the population.
8.18	**Labor force** (A) Employed and registered unemployed (B) Percentage of population. 1989
8.19	**Growth of labor force** Average annual percentage rate of growth. 1981 - 1989

Factor VIII - People
Population Characteristics

	Criterion
8.20	**Female labor force** Percentage of total labor force. 1989
8.21	**Professional women in the workforce** Extent to which professional women are integrated in the workforce.
8.22	**Employment** Total employment (A) Millions. 1989 (B) Percentage of population. 1989
8.23	**Growth of employment** Annual compound percentage change. 1981 - 1989
8.24	**Employment by sector** Percentage of total employment. 1988 (A) Agriculture (B) Industry (C) Services
8.25	**Working week** Hours per week paid per worker in manufacturing activities. 1989
8.26	**Total unemployment** Percentage of labor force. 1989
8.27	**Youth unemployment** Unemployment of population under 24 years as a percentage of total unemployment. 1988
8.28	**Long-term unemployment** Threat of increasing long-term unemployment (more than 1 year) over the next two years.
8.29	**Availability of skilled labor** availability of technically skilled labor.
8.30	**Availability of qualified engineers**
8.31	**Availability of competent senior managers**
8.32	**Workforce immigration** Impact of immigration laws on competitiveness.
8.33	**Worker motivation** Extent to which labor employers strongly identify with company objectives.
8.34	**Employee incentives** Effective use of non-wage employee incentives (such as profit sharing and stock purchase plans)
8.35	**Labor flexibility** Willingness of labor force to retrained or relocated if required.
8.36	**Industrial disputes** Working days lost per 1,000 inhabitants per year. 1987 - 1989 average
8.37	**Industrial disputes** Number of strikes and lock-outs. 1989
8.38	**Industrial relations** Extent to which industrial relations are conducive to labor peace.

Factor VIII - People
Population Characteristics

Criterion

8.39	**Organized labor** Extent to which unions and business managers work together to their mutual benefit.
8.40	**Brain drain** Impact of well-educated people seeking better employment opportunities abroad.
8.41	**Income distribution** Percentage of household incomes going to (1)
8.42	**Cost-of-living comparisons** Cost index of basket of goods in major cities excluding housing. October 1, 1990.
8.43	**Selected consumers price indices, 1989** (A) Food indices (B) Clothing indices (C) Rent indices (D) Fuel and light indices
8.44	**Rent** Average monthly rent in US$, for a comfortable, unfurnished, 3 room apartment in a major city. 1989
8.45	**Urbanization** Impact of trends in urbanization on competitiveness.
8.46	**Urban population** Percentage of total population. 1988
8.47	**Health care** Quality and availability of health care to employees and their families.
8.48	**Alcohol and drug abuse** Impact of alcohol and drug abuse at the work place.
8.49	**Newspaper circulation** Daily circulation per 1,000 inhabitants. 1987
8.50	**Leisure expenditure** US$ per capital. 1988 (A) Personal transport equipment (B) Recreation, entertainment and education (C) Restaurants, personal care, other.

Appendix C

Firm Productivity and Return on Capital

Appendix C: Firm Productivity and Return on Capital

Consider a firm with a linearly homogeneous production function where physical output (value added), y, is produced with two inputs, physical capital, k, and labour, n. The production function, f, is then represented by the equation:

$$y_t = f(n_t, k_t, t),$$

where t denotes an index of time. Fluctuations over time in the output produced from a given level of capital and labour is the standard representation of productivity change.

The assumption of competitive markets -- a standard assumption in productivity analysis -- ensures that the rate of return, R_t, to the capital stock will be equal to the marginal product of capital, or:

$$R_t = \partial y_t/\partial k_t = \partial f(n_t, k_t, t)/\partial k_t.$$

Due to the assumption of linear homogeneity, this relationship can also be expressed in terms of the labour to physical capital ratio, as in:

$$R_t = \partial y_t/\partial k_t = \partial f(n_t/k_t, t)/\partial k_t.$$

The rate of return to physical capital is measured as the ratio of output minus the compensation of employees to the physical capital stock, or:

$$R_t = (y_t - w_t n_t)/k_t,$$

where w_t is the compensation per employee (expressed in real terms so that $w_t n_t$ is a measure of total compensation of employees.

As a particular example of this general methodology, consider a Cobb-Douglas production technology which, after some manipulation, yields the following relationship between the measured rate of return to capital, the labour to physical capital ratio and a time trend:

$$R_t = \propto_0 + \propto_1 t + \propto 2\log(n_t/k_t).$$

Here, the various coefficients are defined as:

$\propto_0$ = a constant representing the average rate of return to capital over time;

$\propto_1$ = a constant equal to the average rate of return to capital multiplied by the average growth rate of total factor productivity; and

$\propto_2$ = a constant equal to the elasticity of output with respect to labour input multiplied against the average rate of return to capital.

In order to incorporate environmental regulations, it is realized that regulations alter the production function. This is typically represented as:

$$y_t = f(n_t, k_t, Z_t, t),$$

where Z_t is a measure of regulatory intensity. Incorporating this amended production function into the same steps as above yields:

$$R_t = \propto_0 + \propto_1 t + \propto 2\log(n_t/k_t) + \propto_3 \log(Z_t),$$

where $\propto_3$ is interpreted as a constant equal to the elasticity of total factor productivity with respect to the level of regulatory intensity multiplied by the average rate of return to capital.

If a suitable measure of regulatory intensity at the firm level is available, it would be possible to estimate this last relationship at the firm level by making use of the financial data described in section 2.3. The key hypothesis of interest would be in terms of the coefficient $\propto_3$, with a negative estimate indicating that a higher degree of environmental regulation reduces total factor productivity (as conventionally calculated) at the firm level.

Appendix D

Further Notes On Methodology and Data Sources

Appendix D: Further Notes On Methodology and Data Sources

Chapter 4 details much of the methodology and data sources used in generating empirical estimates of regulatory impacts on Ontario industrial productivity. In this appendix, we provide further information on the following issues:

- alternative sources examined for data on historical regulatory burden; and
- data sources for measuring future regulatory burden.

Measuring Historical Regulatory Burden

In searching for suitable data to measure historical regulatory burden a number of sources not mentioned in the body of the report were explored. The following summarizes some of the findings of these search.

ACCA-Derived Capital Expenditures

One potential source of data is government programs and tax policies that link expenditures on pollution abatement and control to grants, subsidies or tax incentives. In particular, the federal accelerated capital cost allowance (ACCA) for pollution abatement and control capital expenditures has been a focus for such attempts.[1]

Use of ACCA expenditures calculated from the ACCA have many drawbacks:

- confidentiality restrictions prevent disclosure of industry-specific Ontario claims under the allowance;
- it is unclear whether there is sufficient incentive for firms to classify their investments under the pollution abatement and control provisions of the ACCA. Not only may such expenditures fall under other ACCA categories with similar benefits, but firms must also devote resources to obtaining Environment Canada's approval for their claims;
- not all capital expenditures for pollution abatement and control can be classified as such under the ACCA; and
- claims are not necessarily made during the year in which the expenditures were made and no accurate algorithm exists for calculating expenditures by year; and
- claims are not disaggregated by province.

For these reasons, ACCA-derived expenditures were ruled out as a data source.

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[1] For example, see Conrad and Morrison (1989) and Davey and Bhagat (1979).

Industry Associations

Industry associations offer another potential source for costs imposed on industry by environmental protection regulations. Unfortunately, few associations collect such information. Those that do collect expenditures do so at the national-level only. Although some industry associations disaggregate pollution abatement and control expenditures by province under the assumption that expenditures are proportional to each province's share of industry shipments, this assumption is clearly a significant distortion of actual expenditures.No provincial disaggregation is available.

Occasional Surveys

Government agencies have undertaken a number of surveys of private expenditures on pollution abatement and control. Results have been published in:

- *Market Survey of Environmental Expenditures by Canadian Business* Prepared for Environment Canada by Dun & Bradstreet Canada, 1991;
- *Analysis of the 1989 Pollution Abatement and Control Survey* Prepared by the Investment and Capital Stock Division, Statistics Canada, 1992; and
- *Business Capital Investment in Canada, 1988-1992* Prepared by Industry Policies Directorate, Industry, Science and Technology Canada, 1991.

These surveys provide data going back only as far as 1988. Therefore, they do not allow estimation of Ontario regulatory impacts over the previous decade. Furthermore, data are available only in highly aggregated form, thereby preventing detailed impact assessment.

Corporate Documents

Firms disseminate information through a variety of published and unpublished documents, including annual reports, company press releases, company advertising and trade journals. These sources do contain anecdotal data of firms pollution abatement and control expenditures. Unfortunately, insufficient data were available to support the use of a rigorous analytical framework.

Ministry Audits

From time to time, the Ontario Ministry of the Environment conducts audits of firms that are in violation of Ministry standards. These audits include assessment of firms ability to bear the costs necessary to bring themselves into compliance. Exploration of this potential data source revealed that too few firms have been subject to audits. Those that have undergone Ministry audits did not supply the detailed data necessary to calculate productivity measures. Furthermore, data collected from audits are confidential, thereby preventing release of any detailed findings.

Ministry Discharge Data

In monitoring compliance with current environmental protection requirements, the Ministry collects information on pollution discharges from industrial sources. In the case of water pollution, sampling data are contained in the series of publications:

> Ontario Ministry of the Environment (various years) *Report on the 198_ Industrial Direct Discharges in Ontario* Toronto: Ministry of the Environment.

Unfortunately, similar sampling data are not available for air emissions. Instead, the Ministry develops estimates of air emissions based on assumptions regarding energy and material inputs, production technology, emission control devices installed, etc. These data were deemed inappropriate for the purposes of this study due to difficulties in interpreting their results.

Measuring Future Regulatory Scenarios

Municipal-Industrial Strategy for Abatement

In addition to unpublished data supplied by the Ministry, MISA cost estimates were taken from the following documents:

> Ontario Ministry of the Environment (August 1989) *Monitoring Costs and Their Implications for Direct Dischargers in the Ontario Pulp and Paper Industry* Toronto: Ministry of the Environment.
>
> Ontario Ministry of the Environment (May 1989) *Economic Implications of the MISA Monitoring Regulations on Ontario's Iron and Steel Sector* Toronto: Ministry of the Environment.
>
> Ontario Ministry of the Environment (August 1992) *Economic Assessment of Water Pollution Abatement Options for Ontario Petroleum Refineries* Toronto: Ministry of the Environment.
>
> Ontario Ministry of the Environment (November 1991) "MISA Economic Assessment: Potential Water Pollution Abatement Programs for Ontario Pulp and Paper Mills" Draft #3, November 19, Toronto.

Details on the technology incorporated into each BAT option can also be found in these reports.

Possible Air Regulation Scenarios

Cost estimates for possible air regulation scenarios were obtained from:

> James F. Hickling Management Consulting (July 1990) *Estimation of the Economic Costs and Consequences of Implementing the Proposed Revision to Regulation 308* Toronto: Ministry of the Environment.

The technologies from which the regulatory options were derived are described in:

> Senes (July 1990) *Estimation of Additional Abatement Costs for the Proposed Revisions to Regulation 308* Toronto: Ministry of the Environment.